DOCUMENT RESUME

ED 345 096 CE 061 205

AUTHOR Pillay, Gerald F.
TITLE Training of Middle Level Workers in Singapore. Discussion Paper No. 94.
INSTITUTION International Labour Office, Geneva (Switzerland).
REPORT NO ISBN-92-2-108425-6
PUB DATE 92
NOTE 77p.
AVAILABLE FROM International Labour Office, CH-1211 Geneva 22, Switzerland.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Competence; *Electronics Industry; Electronic Technicians; Employee Attitudes; Employer Attitudes; Employment Practices; Foreign Countries; Interviews; *Job Skills; *Job Training; Occupational Information; *Paraprofessional Personnel; Postsecondary Education; *Technical Occupations
IDENTIFIERS *Singapore

ABSTRACT

Interviews with 42 middle-level technical workers in the electronics industry in six Singapore manufacturing companies explored the training they received. Study findings revealed that technical workers carried out various functions across the whole productive process, including product development and industrial engineering, input, the production line, product testing, and back end. Integral related activities included process engineering, maintenance, and quality assurance. The typical technical worker obtained the Technician Diploma or the Industrial Technician Certificate by full-time institutional training, after school and before national service. These workers were probably pursuing an additional formal qualification through continuing education and training, had been sent by the company to an external training program, and/or had been sent on overseas training. The study found that job skill formation required these prerequisites, generally provided by preparatory and off-the-job formal and nonformal training: personal abilities, technical knowledge and skills, and technological know-how and job knowledge. To attain job competence, the worker needed to develop and apply knowledge, job skills, work skills, and accumulated experience. Three levels of jobs were supervisory, technical, and routine. In companies, line management carried out on-the-job training, implicitly rather than explicitly. No company considered apprenticeship. (YLB)

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TRAINING discussion PAPERS

Training of middle level workers in Singapore

by Gerald F. Pillay

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94

Discussion Paper No. 94

Training of middle level workers in Singapore

by Gerald F. Pillay
Consultant
G F P CONSULTANCY
SINGAPORE

Mr. Gerald F. Pillay has since 1990 practised as a consultant in training matters. Before that he was one of the (then) two Deputy Directors of the Vocational & Industrial Training Board, Singapore and had served in that organisation for 17 years.

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Training Policies Branch
INTERNATIONAL LABOUR OFFICE GENEVA

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ISBN 92-2-108425-6

First published 1992

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Printed by the International Labour Office, Geneva, Switzerland

Foreword

The International Labour Office (ILO) has been concerned with the impact of new technology on middle level technical workers. The focus has been on manufacturing, where technology is applied directly to production of goods.

Its Training Policies Branch has undertaken and commissioned a number of studies, the overall objectives of which have been to understand the work they do, how they acquired the competence and how they have anticipated or responded to technological change.

The concomitant interests have been to understand the policies, programmes and mechanisms adopted by employers, institutions and training authorities to provide opportunities for training and to create the technical manpower needed.

The studies have been of companies in industrialised and newly industrialising countries, the natural environment of front-end and new technology.

The Singapore study complements these. It is specifically focussed on the electronics industry.

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Terms of reference

The Training Department commissioned Mr. Gerald F. Pillay of GFP Consultancy, Singapore to carry out a study on Middle Level Technical Manpower in the electronics industry in Singapore with the following terms of reference:

a. To identify the middle-level technical functions performed in typical current-generation manufacturing firms.

b. To ascertain the profile of the persons actually performing these functions and how they acquired their job competence.

c. To ascertain the training policies and practices of their employers to equip them for their work and anticipate technological change.

d. To ascertain the anticipated changes in the profiles of middle- level technical workers and to identify the action needed or being taken to prepare them.

The core of the study was to interview the technical workers actually performing the job, to capture their experience and perceptions. The other aspects were to be related to this central focus.

The scope of the study was governed by the agreed resources to be deployed. The time frame was flexible.

Implementation of the study

The project was carried out from April 1991 to September 1991, with unavoidable interruptions. Consultations on the draft report took place in November and December 1991.

A. Consultation framework

Mr. Joao-Batista Oliveira, ILO Training Policies Specialist, exercised overall supervision of the project. Mr. Oliveira visited Singapore from 14 May 1991 to 21 May 1991, to participate in the field work.

The Singapore Manufacturers' Association (SMA) agreed to be associated with the study. Mr. Wong Chin Yeow, its Divisional Director, Training & Research, acted as the project's Industry-Based Adviser. He made important inputs to the questionnaire, advised on the choice of companies and exerted his influence to enlist participation. He also carried out selected interviews.

Mr. Ooi Inn Bok, formerly Director, Planning & Policies, Economic Development Board (EDB) and currently Director, German-Singapore Institute, provided much valued encouragement and guidance to understanding of the electronics industry in Singapore. He also advised and exerted influence to enlist participation.

ILO, through the Permanent Secretary, Ministry of Labour, requested and obtained valuable co-operation and support, by way of information about their training activities and exchange of views, from the Economic Development Board (EDB), the Vocational & Industrial Training Board (VITB), the National Productivity Board (NPB), the Singapore Polytechnic (SP) and the Ngee Ann Polytechnic (NP).

B. Methodology

The approach was to capture description and perception, based on a limited selection of companies and technical workers, rather than collection of data or statistics. Therefore, the method of investigation was the free form interview.

The central exercise was interview of the technical worker. A questionnaire was used as a guide to ensure coverage.

The management and institution interviews were not structured.

All interviews were kept as close as possible to one hour, this being the limit of time beyond which companies and individuals were plainly not happy to exceed. All workers and most management personnel interviewed were pulled off the line.

C. Selection of companies

The requirement was to select six manufacturing companies in the electronics industry, typical of the range of production and mix of ownership in Singapore, preferably two large, two medium-sized and two small. It was understood that they should come from the high tech end of the production spectrum.

Taking into account willingness to participate, the manufacturing companies identified, using the conventional criterion of number of regular employees, were:

Large: (>3,000)	one	disk drive final assembly and testing (US MNC)
	one	electronics consumer products, including TV (European MNC)
Medium: (>1,000)	one	micro-chip testing (US MNC)
	one	audio consumer products (Japanese MNC)
Small: (<1,000)	one	PCB board assembly (Singapore MNC)
	one	LAN interface card (Singapore MNC)

In the end the field of industrial electronics was not included. The companies came from the component, computer-related and audio areas of production. Not surprisingly, all were companies with multinational operations.

D. Selection of workers

The selection of the technical workers for interview were was carried out in consultation with management. The workers had to be:

a. performing a middle level technical function;

b. engaged in work related to manufacturing;

c. a member of the regular establishment; and

d. settled into the company and run-in on the job.

Other factors that influenced the actual selection were:

a. availability of the person, eg working shift, working on special projects, urgent line calls, etc.;

b. ability to cope with an interview in English

All workers identified and invited responded to the interviews, which were held during normal hours, although management were aware that interviews could be arranged for any shift hour or day of the week.

In all 42 technical workers were interviewed. The interviews were conducted by Mr. G F Pillay (36), Mr. J.B. Oliveira (four) and Mr. Wong Chin Yeow (two).

All companies included appropriate tours of the company plant. Worker interviews were mostly arranged for in a separate interview room. In most of these cases, the worker and interviewer visited the work site to view or demonstrate the work. In two companies, the interviews were conducted sitting beside the worker at the workstation.

E. Management interviews

Where possible, interviews were conducted with one or more of the following: the personnel director or manager, the production and or engineering directors and or managers and the training manager.

The first priority was to understand the company operations and human resource organisation, in order to identify the workers for interview. Due to constraints of time, the unavailability of the persons concerned and in a few instances a reluctance to be probed on staff policies and practices - manpower is a major area of competition among companies in Singapore - the company side of coverage was limited to the training policies and practices.

F. Institutional visits and interviews

The company interviews were complemented by visits to training agencies and institutions. Besides tours of the training facilities, frank and open discussions were held at each on their training philosophy, their processes of course identification and content and curriculum development, and their support of company training. The following were visited:

a. Vocational & Industrial Training Board

b. Singapore Polytechnic

c. Ngee Ann Polytechnic

d. German-Singapore Institute

e. French-Singapore Institute

f. Japan-Singapore Technical Institute

g. Singapore Technical Institute

h. Electronics Industries Training Centre

A brief description of technical qualifications awarded by institutions in Singapore is given in **Annex I.**

Scope of report

The Report has focused on the technical worker and the training practices of the selected companies. No attempt was made to study market demand or assess the effectiveness of supply. The rich outcomes of the institution visits and discussions have been captured in two parallel reports prepared by the author and Mr. J.B. Oliveira.[1]

A. Definitions

For purposes of the study, "middle level technical manpower" was defined as workers performing technical functions in manufacturing which were below the professional but above the purely operative level, regardless of their qualifications or their designations.

This definition embraced the conventional categories of "technician" and "skilled worker". In this report they are referred to as "technical worker". The essence is a person who applies technical knowledge in his or her work. It proved to be functional for the study.

No clear demarcation or identity emerged for "sub-professional", but this was not an inhibition in any way. The boundary with "operative" was quite clear. However, there emerged a category of "technical operator" or "engineering operator" who performed technical activities and even possessed manual "technical" skills, but with no application of technical knowledge. They were included.

B. Coverage of study

No attempt was made to obtain profiles of the participating companies beyond what was relevant to the study.

No attempt was made to obtain information about wages, compensation packages, terms and conditions of service or the role of unions.

C. Syntax

As the typical technical worker proved to be a male, the pronoun "he" is used throughout, but with syntax "he or she".

D. Interpretation of study findings

The reader is reminded that no formal sampling methodology was applied in the selection of both company and technical worker. The exercise was "dip stick" in nature. The technical functions were identified based on the briefings and in consultation with management. The company then selected the workers for interview based on the given criteria. The study was also governed by availability. Where the first selected worker could not come off the line, a colleague was interview instead.

With a study target of six to ten workers per company, in most instances, only one worker could be interviewed for each major function in a company. However, it was possible to cover the major technical functions in all the companies.

The report should be read as purely investigative and the findings experiential. They reflect what was found. They cannot be taken as either comprehensive or typical. The significant issues high

lighted are case-based. Such generalisations as appear to be warranted must be read in the context of the study.

Finally, the description of job functions and the production organisation, processes and equipment were largely obtained from the interviews of the technical workers and therefore reflect their perception of these.

Acknowledgments

A. Those consulted

The acknowledgements and thanks of ILO and the author are due to:

Mr. Wong Chin Yeow, Director, Training & Research Division, Singapore Manufacturers' Association, for acting as Industry-Based Adviser

Mr. Lin Cheng Ton, Director, Manpower Development, Economic Development Board, for his valued interest and support

Mr. Ooi Inn Bok, Director, German-Singapore Institute, for guidance and advice on the conduct of the study

Mr. Tan Seng Hua, Deputy Director Corporate Services, Mr. Ng Ah Seng, Divisional Director Curriculum Development and Mr. Lam Kin Hong, Divisional Director, Corporate Affairs, Vocational & Industrial Training Board and for their briefings

Mr. Khoo Kay Chai, Principal, Mr. Teh Yap Cheng, Registrar, and Dr. Dave Chong, Head, Electronics & Communication Engineering Department and staff, Singapore Polytechnic and

Mr. F.A. Vasenwala, Deputy Principal (Academic), and Mr. Chan Yoke-Loke, Head, Electronic Engineering Department and staff, Ngee Ann Polytechnic

Dr. Fong Aik Meng, Director, Japan-Singapore Technical Institute, especially for his contributions in the area of mechatronics.

Mr. Lim Sew Hua, Director, French-Singapore Institute

Mr. Francis Yeo Kim Suee, Training Manager, Singapore Technical Institute

Mr. Louis Lim, Executive Director, Electronics Industries Training Centre.

The Permanent Secretary, Ministry of Labour, Singapore.

B. Those who participated

The ILO and author wish to record and extend our warmest appreciation and gratitude to the participating companies for consenting to the study, inevitably at some cost and inconvenience to themselves. According to the understandings on which the study was carried out, they must remain unnamed. Without their willingness to be of service and to share, this Report could not have been undertaken.

We sincerely thank the individual directors, managers, training managers and supervisors who patiently explained their operations, freely shared their views, and assisted in the selection of the technical workers for interview. They too must remain un-named.

Lastly, and most importantly, we thank the technical workers who were interviewed. They also remain unnamed publicly. They participated with enthusiasm, notwithstanding the demands placed on their time. They responded thoughtfully and constructively to the probing questions that had necessarily to be asked. To the extent this Report achieves some useful purpose, they would have contributed much to this result.

Executive summary

A. Findings

The electronics companies studied were part of transnational operations, three of overseas and two of Singapore origin. They engaged in the relatively high-end components of their total manufacturing chain.

They were dominated by rapid evolution of demand, the ceaseless flow of new production technology and the upswings and downturns of the world economy. These factors created an ambient mood of frenetic change and high uncertainty - and yet of challenge - which permeated down to working levels and governed training.

B. Nature of technical work

First finding - the most pervading finding was that the technical workers were perforce mechatronic in orientation, whatever their in-depth specialisation, for they worked in a "mechatronic" environment. They required:

a. Firstly, competence in the mechanical-electrical-electronic interfacing of equipment, systems and finished product.

b. Secondly, grasp of electronic circuitry, as well as of the computer operating system and the application software used.

c. Thirdly, ability to operate in a computerised manufacturing information environment.

Second finding - there were three separate levels of jobs, the supervisory and specialist, the technical and the routine. Technical workers were pressured to move to the next level. The distinguishing feature between levels was the degree of technical and technological knowledge used. The quality of work was determined by the knowledge skills they possessed. Physical skills could be delegated down.

Third finding - the configuration of jobs had been evolving rapidly. There were four clear trends:

a. **"Specialisation"** - with scale and sophistication of line equipment, technical workers tended to be trained in depth in individual series or generations of equipment. The "general purpose" maintenance technical worker was confined to the simpler back end and peripheral equipment, or to the support workshops.

b. **"Integration"** - with the growing "islands of technology" at each workstation, technical workers were becoming responsible for the total functioning of a machine-system or machine-centre. There tended to be no distinction between set up, trouble shooting, yield management, maintenance and repair: The job was keeping the system in production.

c. **"Extension"** - with automated joining of production lines, technical workers were, increasingly, concerned not only with their workstation. They had to work back and forward "along the line" and assume responsibility for correlation, right back to the supply of inputs. They were becoming "systems technicians". Production performance transferred to the technical side as "operations" reduced and eventually became "no man".

d. **"Routinising"** - necessary manual technical processes and procedures were being simplified, e.g. taken over by computerised tools or software, or delegated down. At the lowest level, they were transferred to non-technical people.

Fourth finding - technological efficiency was becoming interlinked, from design for manufacturability to turnaround, downtime and the rejection rate. Technical workers no longer worked in isolation or could keep knowledge to themselves. Each depended on the efficiency of the other.

C. Factors determining job competence

First factor - job skill formation required the following pre-requisites:

1. Personal abilities

a. **Educational attainment** - secondary education, in particular command of language (English in the Singapore environment) and mathematics.

b. **Cognitive skills** - power of logic, analysis, and a relational sense.

c. **Personality development** - maturity, a highly developed sense of job responsibility and ability to work independently (also known as work attitude).

2. Technical knowledge and skills

d. **Fundamental technical knowledge** - core knowledge enabling understanding of production and job functions.

e. **Basic technical skills** - common workshop, laboratory and production tools, instruments and equipment.

3. Technological know-how and job knowledge

f. **Industry** - the product, product market, and the productive process engaged in.

g. **Production function** - the production process, organisation of work, and the standards of work.

h. **Job functions** - the job.

Second factor - skill formation could only take place by doing. The technical worker had, under supervision, to develop, and effectively apply in combination, the following:

a. **Knowledge skills** - the application of technical knowledge and technological know-how to problem analysis during tasks.

b. **Job skills** - physical skills to work and maintain the equipment used and processes carried out.

c. **Work skills** - behavioural abilities like teamwork, communication, planning, organisation, evaluation, and related productivity skills as applied to tasks.

d. **Accumulated experience** - the "E" factor. Mastering the company's accumulated experience of the job, and company culture.

D. Importance of on-the-job training

First conclusion - job skill formation and transfer of accumulated experience were the critical learning processes. These could only be provided by the company. It had to be an individualised process.

Second conclusion - not less than 70 per cent of the company's training efforts should be concentrated on-the-job training. This should represent its major investment in human capital at the technical worker level. It is a continuous and on-going commitment, with each change of job or job-content.

Third conclusion - the following factors were critical to on-the-job training:

a. **Responsibility** - responsibility for on-the-job training had to rest with the line manager. Instruction and "mentorship" must be carried out by the supervisor.

b. **Training skills** - managers and supervisors had to be properly trained in total on-the-job training methodology and skills.

c. **Resources** - it was essential to provide easy access to relevant manuals, manufacturing specifications, company and industry materials and technical literature.

d. **Time** - subject to the dictates of production, technical workers needed time to learn, especially off-the-job on their own.

e. **Opportunity** - it was necessary to create structured learning situations, of which projects and assignments were the most useful.

f. **Documentation** - skill analysis of jobs, individual training and skill profiles and training curriculum should be documented. Accumulated experience should also be captured.

E. Company training practices

On-the-job training had, in all cases, been on-going since the first day, and carried out by line management. This function was, however, mostly implicit, rather than explicit and made accountable. In some cases it tended to be "piece-meal". Line managers and supervisors were not yet systematically given instructional skills or set procedures for actual on-the-job training. Provision of training materials, reading resources, etc, varied. Overall, much remained to be developed to bring on-the-job tr ing to a sophisticated finely matched process addressing present and future needs. There was l evidence of documentation, especially of experience.

No company had considered apprenticeship. Companies seemed disinclined because formal certified training made workers more mobile in the conditions of high turnover characteristic of the labour market. Workers for their part did not want to be bonded, and often preferred to undertake formal courses on their own.

F. Training experiences of technical workers

Although all except four of the 42 interviewed had formal technical qualifications, they generally experienced significant knowledge "gaps" in handling line equipment or functions, also in the repair of mechatronic end-products.

The technical workers themselves stressed the need for formal technical education and training. As a group they believed it was important for their careers to pursue additional or higher formal training. Some nine had obtained their present highest qualification through Continuing Education and Training (CET), and 11 were pursuing courses. There was no suggestion this should be an employer responsibility. Technical workers regarded additional qualifications as "insurance" in case they had to find another job. It gave them mobility.

The technical workers reflected that their companies did conduct or arrange off-the-job training where needed. There was, however, generally lack of a structured approach. The instructors or supervisors were not always the best people for the task of on-the-job training and often did not have the time.

A substantial component of their on-the-job learning was on their own observation and reading (above 50 per cent) and through "Tech-to-Tech" transfer. In some cases, the company expected and relied on this as the operating mode on-the-job.

Technical workers as a group seemed to lack individualised training needs analysis. Generally they also lacked guidance on "what they should know", and how they should integrate private learning with company off-the-job and on-the-job learning.

G. Conclusions

1. From the viewpoint of the company

In future, if not already, the technical workers will be the effective workforce. Their training must be a forefront strategic concern. "Hard skills" training of technical workers must today be given the most critical attention.

First conclusion - attend to the on-the-job training of technical workers; get it done right. A front-end company has to create the job knowledge and skills it needs. After a short while, the technical worker is cumulatively what the company has made or trained him to be. Their training should prepare them for the next evolution of their job or the next higher job.

Second conclusion - simpler "technical" operations should be transferred to non-technical workers, i.e. technical operators or engineering operators. This transfer down points the way for upgrading and continuing careers for operators and re-trained older workers. More important, it is a means to conserve scarce technical manpower.

Third conclusion - on-the-job training must be explicitly implemented as a core function of line managers and supervisors.

Fourth conclusion - training must be installed as a full corporate function. The company's training plans must be recognised as part of corporate tactical planning, implementation of which represents part of new investment.

Fifth conclusion - the training function is multi-layered and multi-process, and must be comprehensively installed. Certain activities must be centrally done, co-ordinated or provided. Likewise skill formation must effectively take place on the line. There must be master trainers at line level. Parallel investments need to be made in curriculum, training materials and resources. Skill attainment must be measured.

Sixth conclusion - it is necessary for a company, subject to its own constraints, to adopt policies that motivate technical workers to learn, find job satisfaction and create a supportive training environment. It would be good policy to make available a fair number of fellowships (or loans) for diploma, advanced diploma and professional courses, with or without appropriate bonding, as an incentive for technical workers - besides being a good investment.

Seventh conclusion - the conscious use of quality circles as a "bottoms up" process to identify training needs and obtain feedback on the training problems is highly recommended.

Eighth conclusion - VITB's new apprenticeship initiatives towards a "dual system" aim to provide skill development for the majority of school-leavers directly entering the market. The electronics industry will have to compete for its supply by offering training "up front", which all other sectors are being encouraged to do. Apprenticeship cannot be avoided. A good apprenticeship programme creates a "purpose-designed" technical individual with good long-term development potential. It is an avenue for non-technical personnel to enlarge into technical roles. An attractive feature is the Singapore Development Fund (SDF) support to be enjoyed. By participating in apprenticeship, a company establishes strong links with education and the public.

Ninth conclusion - the most immediate measure would be to launch the training of key supervisors to be "master trainers". This would, if nothing else, contribute greatly to elevating on-the-job training practices, as the processes in training apprentices are the same as for on-the-job training.

2. From the viewpoint of institutions

First conclusion - knowledge and skills are the prime requirements of technical work, and the evolution will be increasingly in this direction. The demand is clearly for technical workers with knowledge-based, rather than skill-based technical education and training.

Second conclusion - there is demand for the single discipline graduate, but as technological know-how becomes more complex to master, they need more foundation in their discipline. At the same

time, a large number of job functions today are "mechatronic" in nature. The technical worker requires almost equal basic knowledge in mechanical, electrical and electronic engineering as well as information technology, and a fifth component - exposure to how current technology applies these in combination in mechatronic equipment and products.

Third conclusion - it may be possible for "options" to be offered in the final year that better prepare graduates for the industries and job specialisations of their choice in both single and mechatronic programmes. This needs to be complemented by better career guidance.

Fourth conclusion - a conventional two-year full-time programme does not create adequate potential for a middle level technical worker in front-end electronics manufacturing. The desirable norm should be three years, or the equivalent in hours.

Fifth conclusion - CET programmes are vital for complementary upgrading of technical knowledge and filling "gaps". These programmes are as important as full-time training in their contribution to technical worker development. There is scope here to meet specialised industrial needs through endorsement modules, which cannot be included in the main diploma programmes.

Sixth conclusion - a vital training resource is the availability of vendor training centres and programmes and, in the area of work skills and productivity development, the services of the National Productivity Board and training consultants. Vendor field services and training packages also form an invaluable source of on-the-job learning.

Seventh conclusion - the institutions should continue to examine ways to improve entry into and progression within the diploma and advanced diploma courses.

3. From the viewpoint of the technical worker

First conclusion - the technical worker must work at sharpening learning skills, including computing ability. Equally important would be inter-personal skills and a deep understanding of work quality and productivity.

Second conclusion - the technical worker cannot rest on competence in his job. He must aim for mastery. He must be ready for change. He must progressively upgrade his technical knowledge and widen his command of company technological know-how. Formally, the immediate objective and most appropriate upgrading would be to obtain the Tech Dip or Advanced Tech Dip.

Third conclusion - finally, the technical worker must have a "development map". He must know what he should know, or establish this, and methodically pursue it, adjusting and modifying as requirements change.

H. Beyond the present

There appeared to be a requirement for middle level technical workers in the area of sales, consumer education, customer after-sales service, training, and technical backup. An area not covered, but critical to the industry, was the quality of vendor field services for highly sophisticated products. The middle level technical worker would have major roles in these sectors. They also provide career avenues for mature technical workers.

The real issue is training them for the next generation of specialised, integrated and extended job functions, provided they are trainable. This emphasises the central message from the study that the technical worker must be seen as a deployable resource created by the company. The more thoughtful, anticipatory and thorough the total training process, the more ready is the technical worker for deployment as soon as releasable.

The Report "P2000" of National Productivity Board (NPB), which set the national strategies for the decade, sums up the key corporate training objectives companies should be looking at:

> "Training will have to be planned, structured and undertaken to meet the business goals of companies."

"In the 1990s, trainers should be regarded as performance managers, as they are responsible for training up our human resources."

In these efforts, the technical worker will occupy a critical place.

I. The electronics industry in Singapore

With a population of 3.0m and a per capita income of US$ 10,240, the island state of Singapore is commonly referred to as a Newly Industrialising Economy (NIE). Singapore's only resource is its workforce of 1.5m. It is short of manpower in absolute terms.

Economic development has been led by the manufacturing sector since independence in 1965. With diversification in the last decade, finance, manufacturing, commerce and other services, in that order, now form the major components of the economy. In 1990, manufacturing accounted for 29.1 per cent of GDP, and was the largest employer with 28.4 per cent of the workforce.

Within manufacturing, the electronics industry forms the largest component. In 1990, it was responsible for 38.9 per cent of the output of that sector, totalling US$15,351m. It employed 35.6 per cent of the manufacturing workforce.

From one factory producing black & white TV sets in 1965, Singapore has participated in the various evolutionary stages of this transnational industry, with its continuously restructuring international division of production functions. The main stages of growth of the industry have been:

a. 1965-79 - Responding to, in fact vigorously wooing, the then "off-shore" explosion of the MNCs, Singapore saw the growth of establishments to 168, performing the assembly-type labour intensive components of production, competing on the basis of still cheap and available labour.

b. 1979-85 - With full employment, increasing cost of labour and, most importantly, with increasing availability of technical manpower as a result of massive investments in pre-employment training and computer education, the industry was able progressively to compete for more technology-intensive components of production, expand output without significant increase of establishments or workforce, and develop local support infrastructure. Census Value-Added per Worker rose from US$10,600 to US$24,100.

c. 1985-90 - Singapore made significant expansion and qualitative gains in this period. The number of establishments grew to 245 and the workforce doubled, while output tripled. The Census Value Added per Worker rose to US$34,100. Four features characterised this period. First, companies successfully transferred in increasingly high-end production segments, both front-end customisation and back-end final product testing and commissioning. Secondly, they transferred out labour intensive and less skilled assembly work, managing, supervising and providing technical support from Singapore. Thirdly, Singapore began to see company growth by vertical integration and the setting up of major new integrated manufacturing facilities based on automated, robotised and FMS technology. And fourthly, many local companies achieved full development and moved to become MNCs in their own right through "off shore" production on the one hand and "reverse" development of overseas R&D, design, prototype and marketing capabilities, in the US in particular.

Today, Singapore is a major focus of the transnational electronics industry. It is the world's largest manufacturer of hard disk drives. The export value of this item alone in 1990 nearly equalled the total output value of Singapore's petroleum industry (which boasts five refineries). In the areas of component and

industrial electronics, it has added considerable customised capability to undertake IC design, wafer and chip fabrication and testing, high-end PCB design, fabrication and assembly, product development and turnkey hardware-software systems development. The industrial and consumer final products include, besides disk drives of various sizes, PCs, peripherals and office equipment; audio, TV and VCR equipment; telephone digital switching and peripheral equipment, connectors and medical as well as defence equipment. Several major MNCs have established R&D facilities. The support infrastructure has deepened.

Of the electronics establishments, 60 per cent are either owned by foreign MNCs or joint-ventures; by asset or output value, the figure is higher. This is due, inter alia, to Singapore enjoying top placings among countries as an investment environment, especially for labour productivity, efficiency and stability - factors critical to this capital intensive, competition-volatile and quick response industry. Of the 245 current establishments, 108 are on "pioneer" status, reflecting their relatively recent establishment. These employed three quarters of the industry's workforce and accounted for the same proportion of its output in 1990.

The availability of engineers and middle level technical manpower must be reckoned to be a factor enabling the development of the industry.

II. Participating companies

The five companies studied reflect a fair cross-section of the industry, viz:

Large: (>3,000)	one	disk drive final assembly and testing (US MNC)
Medium: (>1,000)	one	micro-chip testing (US MNC)
	one	audio consumer products (Japanese MNC)
Small: (<1,000)	one	PCB assembly (Singapore MNC)
	one	LAN interface card (Singapore MNC)

The companies came from the component, computer-related and audio areas of production.

A. Company A

This company was incorporated in Singapore in 1987, by a United States corporation which was itself established in 1986 to manufacture hard disk drives. The Singapore establishment was the MNC's first production plant, commencing operations in the same year. The MNC has since "cloned" the Singapore production facility in Penang (1988), Inverness Scotland (1989) and Ivrea, Italy (1990). Its headquarters is in San Jose, California with a R&D facility in Colorado.

The company's growth has been phenomenal. In 1990, sales turnover was USD1.34b, giving it a listing in Fortune 500. A major proportion of the output came from Singapore.

Company A manufactures 3.5" and 2.5" hard disk drives. It was the first to go into production of the 2.5" drive. Production is customised to the requirements of the client. The company's business approach is " design for manufacture". The company manufactures for a wide range of major OEM manufacturers of PCs, laptops and notebooks.

The organisation of production is as follows:

a. Marketing is done on a world wide basis from the United States. There is a branch of the US sales office in Singapore looking after the regional market.

b. Customisation, product specifications, functional and product design, prototyping, and trial production is done in the US. Likewise, determination of the production process, component specifications, quantities and test specifications.

c. The Singapore company receives its production orders from the United States, together with the product and production specifications. The core of the Singapore operation is to assemble the Hard Disk Assembly (HDA), couple to it the Printed Circuit Board Assembly (PCBA), test and QA the assembled final product to specifications, and ship it to the customer.

d. The PCBAs, the components of the HDA, i.e. the actuator, head stack, drive, disks, etc., are either drawn from overseas standing suppliers or sub-contracted out locally.

e. Singapore is the central repair centre for defective disk drives world wide. These are shipped (by air) for diagnosis, repair, component replacement, re-assembly, re-testing and re-certification and QA, and then shipped back.

f. Singapore is also the production line development and automation centre world wide. Its Automation Department has developed and installed automated assembly lines not only in Singapore but in Scotland and Italy. Penang has been

developed by transfer, also carried out from Singapore, of its replaced less-automated production line. The heads of the other "off shore" facilities report to the Senior Vice President, Singapore.

Through put is about 20,000 new and 2,000 repaired units a day.

In Singapore there are three physically separated plants:

a. **Singapore 3 (S.3)** - The newest, set up in 1990 as the current-generation production facility. It comprises 4 identical lines configured for different product ranges. The principal activity, the assembly, is carried out in the 4 Class 100 Clean Rooms, two of which are substantially robotised and automated. The pre-assembly and post-assembly phases are necessarily labour intensive. S.3 also houses the headquarters, the main technical and engineering support, and Training Centre.

b. **The Repair Centre (S.2)** - set up in 1988 as a production centre. The line is now devoted to world wide repair and re-certification.

c. **The Automation Department (S.1)** - the original centre set up in 1987 and used for prototyping and constructing the next-generation automated and robotised production lines for installation in the "off shore" facilities. This facility was closed down in September 1991 and the line-development function integrated into S.3.

The organisation of manufacture at S.3 follows the conventional structuring of an engineering company, with manufacturing, product, process, maintenance and test engineering and QA forming the main relevant components - where the middle level technical manpower mostly are. S.2 duplicates the production facilities of S.3, while sharing centralised technical and training support.

The company has a total regular establishment strength of 5,000. Of these some 150 are engineers and 350 middle level technical manpower, and some 3,000 operators.

The company has a Training Department, with two training managers, in charge of management and production training respectively.

B. Company B

Company B was established in Singapore in 1984, by a US multinational which was itself set up in 1969 in Sunnyvale, California. Its business is manufacture of integrated circuit devices, i.e. ICs. The company's first "off-shore" facility was set up in Penang, Malaysia in 1972 and the next in the Philippines in 1975, the latter has since been bought up by one of its subcontractors. In 1986, the company duplicated its Singapore facility in Bangkok. The company also has manufacturing facilities in Japan and the United Kingdom.

The company objective is "to supply total high performance system solutions based on sub-micron technology leadership and innovative design for manufacture of telecommunications and computation (C & C) equipment. It is one of the top ten US producers of micro-devices. The products are typically customised and small batch, but include standardised products. The range covers:

a. devices for micro-processor based products
b. high-performance memory chips (4 MB and above)
c. programmable logic devices
d. telecommunication devices

In 1990, it produced some 60 per cent of the world supply of PC and Laptop microprocessors.

The company's production is organised along a geographical division of labour. Singapore handles exclusively the back-end or final testing of the company's high end devices before shipment to the customer. The Average Selling Price (ASP) of each unit is around US$10, as against one dollar for conventional chips.

Aside from a regional marketing branch, the Singapore facility is housed in part of a flatted factory complex, with two complete production floors, each flexibly set up to handle a large number of small batches simultaneously. Production organisation is conventional, with product engineering, production control, manufacturing, process engineering, test & maintenance engineering, and QA being the relevant components.

Because of the short-run nature of test batches, the operational set up comprises "islands" of stand-alone high tech test functions, supported by manual interfaces which appear to be in the process, where possible, of automation. The core plant is the Test System, essentially a massive purpose-designed computer system. There are some 40 such systems in all, including not less that 17 industry-standard state-of-the-art Teradyne systems, each able to run up to 5 test lines (Test Handlers) simultaneously. Older-generation equipment, e.g. Ximcom, has been phased out to Penang.

The organisation of production is as follows:

a. Allocation of batches are made in the United States, based on knowledge of the Singapore capability and availability. Where a new product or new technology is involved, the United States consults Singapore on the test requirements and its capability to meet these, throughout the design and prototyping stages. "Qualification batches" are sent to Singapore for detailing of the test process, for modification of the input and output stages including acquisition of new equipment, and for debugging of the process and test software on the Singapore machines. A typical case was the testing of Plastic Quad Flat Pack (PQFP) range introduced in 1990.

b. Depending on the device specifications, the stages of production are:
   1. incoming QC and VMI
   2. test
   3. mark
   4. post-Mark test (also Burn In as required)
   5. hermatic and VMI test, and
   6. packing

   Devices of all classes are tested in Singapore, including Dual-in-Line Pins (DIPs) and Leadless and Flat Pack Chip Carriers, both plastic and ceramic.

c. Typically, there could be 1,000 batch set-ups a week, with a throughput of 3,000 units per hour.

The Singapore company has a workforce of over 1,000, of whom 170 comprise middle level technical manpower. Of the latter, some 120 are engineering assistants and the remaining 50 are technicians. The former are in charge of test process development, qualifying new equipment, and line functioning of the Test Systems and Test Handlers. The technicians perform set-up, initial fault diagnosis, line clearance, and maintenance functions and are also responsible for most of the largely mechanical input-output and "back=end" equipment and processes, including workshop activities.

Training has necessarily been an on-going activity since inception. In 1990, the company established a Training Department.

C. Company C

Company C, a subsidiary of a Japanese multinational conglomerate, was established in 1977. It is accommodated in its own self-contained factory grounds. It is one of nine "sister companies" in Singapore producing different products, with one responsible for regional sales. The business of Company C is the production of finished consumer audio products of a reknowned Japanese brand name. From small beginnings, the company has an annual turnover of US$330m, and enjoys a sizeable segment of the world market in its field.

The products of the company fall into three categories:

a. **General audio** - these include portable radios, radio-clocks, radio-cassette recorders, tape-recorders, etc.

b. **Home entertainment systems** - tuners, amplifiers, speakers, and related Hifi equipment. The staple output is the "3 piece system."

c. **"Kit"** - a range of products packaged in "knock-down" condition for export to certain countries. These kits are also supplied to agents.

The company was originally engaged in "offshore" labour intensive assembly. With scarcity of labour and increasing availability of technical manpower, it has moved since the mid-1980s, through vertical integration, on the one hand towards total in house integrated production based on mechanisation and automation and on the other towards independent product design and marketing. This has been reflected in a number of developments, viz:

a. Creation of an R&D division, including a new products department, progressively to achieve 100 per cent design of its products. The target is now at least one new product a year.

b. Creation of an In-House Production division, with three specialised departments, viz (1) the fully automated and robotised Parts Manufacturing department which produces plastic and metal components; (2) the Mechanisms department which produces mechanical parts using Flexible Manufacturing Systems (FMS) lines; and (3) the Auto Insertion department which produces the bulk in house PCBA requirements using a range of Panasert machines on automated lines.

c. Creation of a Marketing and Sales division, directly responsible for company sales.

d. Both Production Control and Industrial Engineering have added capability to exercise direct control of inputs and components and to design and install automated productions systems.

The company is the first among the overseas establishments of the group to have evolved all the components of a fully independent integrated production facility.

In terms of manufacturing organisation, the new and expanded divisions and departments mentioned above support the Production division, which has the two core production departments of Final Assembly I and Final Assembly II. The division also has its own Production Maintenance department, which is responsible for all technical line operations, maintenance, clearance and repair. Reflective of the emphasis on product quality in a highly competitive consumer market, the QA function is a large and rigorous one, comprising Component QA, Production QA and Market QA.

The company has a regular staff establishment of close to 3,000. Of these some 100 are engineers and some 300 are technical workers. About half of the latter are engineering assistants and the remainder technicians.

The majority of the technical workers are distributed in the Production department. Interestingly, in the fully automated departments, where there are no operators, the technical workers and supervisors take on "manufacturing" responsibilities as well, i.e. for material and component inputs and product (parts and mechanisms) output as well. There are examples of middle level workers supporting R& D and industrial engineering as well.

Training has been an on-going activity since inception. The company set up a Training Department with a Training Manager in 1989. The department has two full time training officers.

D. Company D

Company D is a Singapore company established in 1978, to manufacture low value-added products such as electronic calculators, games and toys. Today, while the company's core busi-

ness remains as contract manufacturer of higher value-added consumer and industrial products and Printed Circuit Boards Assemblies (PCBAs) for major OEM, it has diversified into areas such as plastics toolings, precision mouldings, strategic investments, interactive entertainment and medical electronics.

Products manufactured include computers and peripherals, translators and other computerised equipment.

Milestones in its history include establishment of the company's first "off-shore" operation in Kulim, Kedah, in West Malaysia. It also subsequently incorporated Healthcheck Corporation of the United States, which makes non-invasive consumer health care products, in 1984. It quickly followed this up with a Joint Venture in China in 1986.

The company was listed on the Stock Exchange of Singapore's SESDAQ[3] system in 1987 and upgraded to the MainBoard in 1990. The year before, in 1989, it consolidated its local operations into its own building. The company also initiated the establishment of its newest "off-shore" operation in Batam Island, Rhiau Province, Indonesia in 1990. This facility is expected to go into commercial production in the last quarter of 1991.

The company is among the leading and largest contract manufacturers of PCB assemblies in Southeast Asia. It has secured this by:

a. Strategic and heavy investment in Surface Mount Technology (SMT) equipment to maintain a technological advantage. It is a leader among the four or five companies in Singapore with substantial SMT capability, enabling it to compete world wide for major clients.

b. Developing the capability to engage with clients and partners at the earliest stages of circuit design, so as to maximise manufacturing productivity at the best price.

c. Developing next generation products and processes and marketing capability overseas, particularly in the US.

Company D has embarked on diversification into consumer electronics. It manufactures language translators, an acquired United States design which it has improved. It is currently venturing into development, with a US partner, of an interactive terminal for end-users to participate in on-line networked programmes, e.g. homeviewers' "live" quiz shows.

Production batches are typically small and in short runs. Again, invariably, the batches involve "mixed" components. Production is organised on the "islands of automation" principle, with both automated and manual interfacing. The manufacturing facilities comprise two completely independent production floors , each flexibly configured to run several products simultaneously. Each has the following "discrete" production facilities, which products pass through according to specification:

a. SMT mount station(s)
b. auto insert stations
c. manual stations
d. component test
e. functional test
f. VMI, QA and packing

The company's SMT machines are equipped with vision technology.

The company has a regular staff strength of 750, of whom 70 are engineers and 100 middle level technical manpower, about equal in proportion as between engineering assistants and technicians.

Training has been an on-going activity since inception. Training is planned and structured so as to be pro-active.

E. Company E

Company E is a small Singapore company first established in 1980 as a partnership, to be sales agent and distributor of PCs, peripherals and software. With a grant from the Economic Development Board, it moved to manufacturing in 1987, when it was at the same time incorporated as a limited company. Its first product was an ArcNet network interface card (NIC).

Today, this has been expanded to a whole range of NICs in the ArcNet and EtherNet ranges, these being established industry standards for networking hardware for support of Novell's Netware Local Area Network (LAN) Operating System. Novell has accorded it OEM status. Since 1990, the company also offers its own line of PC workstations and file servers, installed with its NICs, as total LAN systems solutions. In 1991, the company launched its own low-cost LAN Operating System called "Ready-Link" for small systems users, as well as its own Notebook. Its "Thick Ethernet", inclusive of repeater and multi-media concentrators, can support up to 500 workstations, and with extensions WAN (Wide Area Network) systems as well.

In 1987, the company established a majority-owned partnership under the same name in the United States to act both as a conduit for new technology and as a marketing window. In 1988, it established an R&D Department, to act as its cutting edge in its field.

In Singapore, the company is housed in two locations, its original sales office and a factory building acquired in 1988. It is developing a third facility which will enable in house production to work which is now contracted out.

The organisation of production is as follows:

a. Its cutting edge lies in the design of its Application Specific Integrated Chip (ASIC) and the NIC circuitry, carried out by its R&D department. These have consistently bettered industry standards of performance, with smaller card size and lower power consumption. The chip is prototyped and manufactured by specialised contractors. The PCB Assembly or card is prototyped in house.

b. The production of the card (ie the NIC) is also subcontracted out.

c. The final testing, VMI and QA of the card is carried out in house.

d. The PC workstations, fileservers and notebooks are also assembled in house, but the parts and PCBAs are contracted out or obtained from suppliers.

e. The company operates a Service Centre to repair its products. The Service department supports Sales in the installing and commissioning of its LAN systems, as well as the other products in respect of which the company still carries on a substantial agency business.

Production is by batch according to order. Production of NICs is about 1,000 per month, production of PCs, etc. is just commencing. The production functions comprise:

For net interface cards

a. incoming QC inspection
b. burn in
c. functional test
d. repair
e. VMI & QA
f. packing

For PC, etc assembly

a. incoming QC
b. assembly
c. functional,Drop etc test
d. VMI & QA
e. packing

Service centre

a. customer technical services (on-line)
b. incoming check and first line fault clearance
c. diagnosis and repair
d. installation and commissioning

The production of NICs and PCs etc., is carried out together sharing a common set of facilities, technical workers and operators. The service facilities are separate.

Company E has a total workforce of 121. Of these the majority are sales and service personnel. On the technical side, there are ten engineers and 14 middle level technical workers, six in production and four in the service.

Training has been an on-going activity since inception. This has been and continues to be the responsibility of the line managers. There is as yet no Training function.

F. General observations

The companies studied reflect considerable diversity in the segments of the electronics market in which they operate, as well as the component of the manufacturing process they undertake.

They reflect the relative maturing of the industry in the following characteristics:

a. They are specialised, and the range is wide.

b. They are technology intensive. This is reflected in a combination of capital and knowledge-knowhow intensity. Small is viable, as demand is customised and subcontracting is possible.

c. The companies have moved upwards and outward, to win competitive margins. "Offshore" transfers and acquisition have taken place in product generation and design capability-linkages, as well as labour intensive operations.

d. Operator dependence is relative to scale, rather than process. The crucial requirement is for engineers and middle level technical manpower.

III. Profile of the technical worker

A. Preliminary remarks

Besides the factors governing selection of technical workers for interview, the following need to be borne in mind:

a. It can be expected that the companies will have selected the "good" or "better" workers, who reflect well on themselves, rather than "poor" workers.

b. With manpower scarcity and "fierce" competition for resources in the labour market, companies will employ and/or deploy all those available in house and who can do or learn the job. There is little room for preferences whether for paper qualifications or otherwise.

c. By their established position in the industry the five companies enjoy equal competition for technical manpower. Therefore, the fields from which they recruited would not have had in-built biases.

These factors have operated to the advantage of the study - which would wish to avoid cases of individual difficulty or distorting factors.

B. Characteristics of the group

The total number of technical workers interviewed according to company was as follows:

Company	No.
A	11
B	10
C	10
D	6
E	5
Total	42

For record purposes, of the total of 42:

a. 31 were males and 11 females

b. 34 were single and eight married

c. 35 were Singapore citizens, 3 were Malaysian citizens with permanent residence, and 4 were Malaysians on work permits

d. 36 were Chinese, three Malays, two Indians and one Other (Eurasian)

Their age distribution was:

Range (Years)	No.
30-34	3
27-29	11
24-26	21
21-23	7
Total	42

The breakdown of the technical workers by area of work and designation was as follows:

Area of Work	Designation				
	Svsr	EA	Tech	OTW*	Total
Production					
R&D,design and product dev		2	1		3
Industrial engineering, (including plant automation)		2	1		3
Line mfg operations	1	2		1	4
Product testing (including re-work)	3	3	3	1	10
Finishing & packing (back-end)					0
Support					
Maintenance of line, test & back-end equipment & sys	4	3	9		16
Process (Maintenance of yield)	1	2			3
QA		1		1	2
Customer technical services			1		1
Total	9	15	15	3	42

* Other Technical Worker

The technical workers by area of work and qualifications at time of interview were as follows:

Area of work	Qualification level*				
	Dip	ITC	NTC	Other	Total
Production					
R&D, design and product dev	2	1			3
Industrial engineering, (including plant automation)	1	2			3
Line mfg operations	1	2		1	4
Product testing (including re-work)	5	3	1	1	10
Finishing & packing					0
Support					
Mfg equipment maintenance	4	8	3	1	16
Process (maintenance of yield)	3				3
QA	1			1	2
Customer technical services			1		1
Total	17	17	4	4	42

* Or equivalent

The breakdown of technical workers by field of specialisation and qualification is as follows:

Field of specialisation	Qualification level*				
	Dip	ITC	NTC	Nil	Total
Electronics (including communications) eng	11	8	1		20
Industrial electronics eng		3			3
Electrical eng	3	1	1		5
Mechatronics (including electro-mechanical servicing)		2	1		3
Mechanical eng	2	2	1		5
Production eng	1				1
Automotive eng		1			1
No qualification				4	4
Total	17	17	4	4	42

* Or equivalent

The technical workers by total working experience and level broke down as follows:

Area of work	Working experience (years)						
	10& >	7-9	5-6	3-4	2	1& <	Total
Supervisor	6			2	1		9
Engineering assistant	1	2	4	3	1	4	15
Technician	1	1	3	4	3	3	15
Other technical worker		1	1	1			3
Total	8	4	8	10	5	7	42

The technical workers by length of service in company and level was as follows:

Level	Company service (years)						
	10& >	7-9	5-6	3-4	2	1& <	Total
Supervisor		1	1	3	2	2	9
Engineering assistant				3	6	6	15
Technician			1	5	4	5	15
Other technical worker		1		1		1	3
Total	0	2	2	12	12	14	42

The breakdown of the technical workers by years of previous employment (before joining the company) was as follows:

Level	Previous employment (years)							
	10& >	7-9	5-6	3-4	2	1	Nil	Total
Supervisor	3		2	1			3	9
Engineering assistant		1	1	4	2	1	6	15
Technician	1		1	2			11	15
Other technical worker			1	1			1	3
Total	4	1	5	8	5	1	21	42

The breakdown of the group by number of jobs before joining company was as follows:

Level	No. of previous jobs						
	5	4	3	2	1	Nil	Total
Supervisor			6		3		9
Engineering assistant			3	6	6		15
Technician		2		1	3	9	15
Other technical worker			1		1	1	3
Total	0	2	10	7	13	10	42

C. Summary of technical worker profile

In terms of personal particulars, the typical technical worker was a Singapore citizen, male, Chinese, single, and 24-26 years of age.

He would possess either the Tech Dip or the ITC, obtained by institutional training at either the polytechnics or the Singapore Technical Institute, an institution of the Vocational & Industrial Training Board (VITB). He was likely to have qualified in electronics engineering.

He would be employed as an Engineering assistant (EA) or Technician (Tech), and be deployed either in maintenance or operations.

For the typical technical worker the present company was likely to be his second employer. He would have been recruited with 3-4 years of previous employment experience, and would have 2-4 years of service with the company.

IV. What do technical workers do?

The study revealed that technical workers carried out various middle level technical functions across the whole productive process. However, it was only possible to interview a limited number from each work area or sub-area. In some areas, they were absent or the component was not prominent in the companies studied.

As it turned out, all the core functions were covered. The categories adopted have, however, been rationalised for presentation purposes. Different companies used different appellations and structures to define and organise their work.

Rather than do an exhaustive catalogue, this report highlights typical and meaningful examples, to bring out what they do.

A. R&D, design, product development & product engineering

The study reviewed two technical workers in this area. One was an EA and the other a technician.

The former, recruited only one year previously, possessed the Tech Dip in Electronics and Communications. He was assigned to the new R&D department of Company C which produced audio equipment on an integrated basis in house. It had adopted an immediate target of at least one new product a year.

The core function of the department was producing new models of the product lines. The functional and product designs were still based on specifications laid down by the "home" base. The local content lay in refining and making improvements within these specifications, driven simultaneously by considerations of how to manufacture the items more cost-efficiently at the local plant. Many products of different complexity were being processed at the same time. As local expertise had increased, the latitude to design for manufacture increased.

The work was organised in four groups, of which the EA's was Group 3 (Electronics), led by one engineer with nine EAs. Essentially, Group 4 (mechanical) designed the "case" and Group 3 the PCB assembly and linkages. There was, accordingly, considerable call for in-group as well as inter-group teamwork, to "match" the whole together. The EA's group was assigned a project to develop a new two band portable radio, a minor product, but which reflected a true transfer of R&D function.

While the core of Group 3's work lay in electronics, i.e. circuit board sub-assembly, even at the EA level, designing for manufacture involved knowledge of - and ability to gauge the implications for - the manufacture of the mechanisms and parts, and for the final assembly. Other components of requisite knowledge-skills included accessing and applying:

a. international standards and specifications of the company;
b. market information on the consumers' preferences in the target market;
c. standard components, materials and parts of the company;
d. the manufacturing capability of the local plant, i.e. PCB assembly; and
e. the cost of manufacturing.

Under the guidance of the engineer, the EA carried out the following stages of work independently:

a. designed and laid out the PCB circuitry, using special company CAD software for copper patterns;
b. built the prototypes and tested them;
c. documented the final specifications in the form of manufacturing instructions.

The other technical worker, a Technician, also recruited only a year previously, possessed the ITC in Electronics Engineering. She was assigned to the Product Development department of Company D, a specialist PCB assembly contractor which was also diversifying into its own consumer products.

The core outputs of the department were PCBA designs and finished products, including "casings", for clients and for their own products.

Under the guidance of the engineers, the Technician carried out the following functions:

a. detailed out circuit diagrams, using a commercially available EDA/CAD/CAM software package;
b. constructed PCBAs, and modified them as the product developed;
c. built the testing systems for them;
d. carried out component and functional testing.

At the other companies, Company E's R&D function, namely ASIC chip design and development, was carried out by engineers. No technical workers were involved. The Product Engineering department of Company B, which "prequalified" micro-device batches and their test software for production testing, also did not use technical workers.

B. Industrial engineering

This category broadly related to the design and installation of the line for manufacturing the product. It included investigating new equipment to be bought or transferred in, designing, installing and "qualifying" new machines and systems, and upgrading and automating existing lines. Every one of the five companies had recently completed line installations and were installing major new lines locally or "off-shore". The work calls for combination of mechanical, electrical and electronic inputs. It is a major area of use and training opportunities for technical workers.

Three technical workers were reviewed from this area of work. One was an EA and two technicians.

The EA and one technician worked in the Automation Department of Company A. They are engaged in building a fully automated line for Head Assembly (HDA) of hard disk drives, in fact the third such installation - the first two having been installed in the main plant (S.3) in Singapore and in Italy respectively. The work was undertaken by three Sections: Mechanical, Electrical and Control. The Mechanical Section installed the static workstations and the robots, including the power leads up to the control box. The Electrical Section wired up the system including the conveyor. The Control Section programmed the robots and other workstations, and installed and tested the systems control software. The EA was in Control and the Technician in Mechanical.

Within the Section, the EA, who possessed an ITC in Electrical Engineering, was responsible for the "Hard-Tooling" workstations (on the earlier line, she was responsible for the robot workstations). Her work functions included, for each station:

a. Design the workstation - calculate the spacing between stations, confirm spaces and accesses for moving arms, tooling and maintenance, and design jigs and fixtures, etc needed.

b. Do detailed drawings of the workstation, using CAD equipment.

c. Draw up specifications and call for quotations for parts, evaluate, negotiate, and supervise installation.

d. Draw up the operating sequences, which control needed for programming.

e. Set up the workstation, including the pneumatics, sensors and power supply leads up to the terminal block.

f. Upon programming and hook up, trouble shoot and write trouble shoot guidelines for eventual Line users.

The work functions of the Technician, who also possessed a Tech Dip in electrical engineering just obtained through part time study, were:

a. Write programmes based on pre-discussed equipment moves and timings, using PLCC via laptop PC.

b. Carry out checks of workstation, e.g. that end-effectors ("hands") and sensors were in place and power, air supply, spacing, etc were in order.

c. Load, run and de-bug stations. Make changes to programme.

d. Change PLCCs where necessary, drawing up specifications and sub-contracting out.

e. De-bug card-PLCC interfaces, and change cards where necessary.

f. Hook up and test the total system, including designing the simulation data (loads) for the test.

The current line under construction comprised 60 workstations, including four robots (4-axis). The majority were Automatic PackWriters, the rest being balancers, de-gaussers and head alignment machines. All work was overseen by the relevant engineers. The technical workers however carried out their jobs independently. The typical site scene was one of several technicians from the different sections working together.

The third technician, who with eight years working experience had acquired an ITC through part time study, was employed in the Industrial Engineering department of Company C. His functions included installing new equipment on the line, similar to the EA above, trouble shooting new equipment, and assisting in the off-line repair of major "down" equipment.

C. Line manufacturing operations

This category of technical worker dealt with set up and trouble shooting functions, in direct support of Manufacturing. Four technical workers were reviewed under this category. Three belonged to Company B. Because of the multiplicity of the IC test lines in this company, the extreme speed and short duration of each batch run, the number of set ups in a shift and the cost of down time, separate crews of technical workers were deployed purely on these functions. In the other companies, they were integrated into the functions of line maintenance technical workers.

The fourth technical worker was the QA/production supervisor of Company E, who assumed overall responsibility for the production line, including trouble shooting.

The details of line support work are described under line maintenance functions. Suffice it here to describe the set up functions on the test line in Company B as an example of "technical" duties being carried out by a person with secondary education ("A" levels) but without (yet) technical qualifications, namely the sole Trainee Technician interviewed. His job tasks, when a workstation signalled for set up, were:

a. Calibrate the test head and system - this involved loading test software from host or tape, issuing commands to test the electrical condition of the Tester, compare with laid down parameters, adjust System to compensate for resistance, timing delays, etc, and run a manual test with a batch of correlation or reference units.

b. Prepare the test handler - align the input tracks, stop-bars, conveyors, balance for equalisation of pressure to pin the device legs, set test temperature requirements,

hook on liquid nitrogen (LN2) tanks if needed, and complete visual checks.

c. Dock the handler to test head - check that the contacter board (a large PCB interface with pin positions to link the two) was correctly set up (by another section) and carry out actual physical docking.

d. Verify the set up - run a correlation batch, make adjustments to the test system settings, the handler and contacter load board and to the docking, until the acceptable yield (95 per cent) was attained.

The work tasks involved precise and detailed "lay" knowledge of the functioning and characteristics of the hardware, software and product, and the ability and confidence to physically manipulate the equipment as well as the application (test) and utility/diagnostic software.

D. Product testing

A major stage of manufacture was the functional testing of each component, sub-assembly and finished product. Testing was carried out 100 per cent on units as a line activity, "Failed" units were sent for failure analysis and re-working, and then returned to the testing cycle. Components and sub-assemblies might be tested in different temperatures and other environments.

There were ten technical workers engaged in this area. Six came from Company A, whose business was making hard disk drives, two from Company E at which the principal in house activity was the testing of LAN cards and two from Company D which assembled PCBs. Two were in functional test, four were in failure analysis, and three were doing a combination of failure analysis and re-work. Three were supervisors.

A good example was provided by the Senior Engineering Assistant (SEA) in Company A, dealing with Failure Analysis (FA) at the repair centre (S.2). With 14 years' working experience, he possessed the City & Guilds of London Institute Full Technological Certificate (FTC) in Mechanical Engineering, obtained part-time while in the Navy, after completing four years' apprenticeship as a Naval Technician. His duties involved carrying out investigation and re-work/repair of the "failed" Head Assemblies (HDAs).

In the manufacture of the hard disk drive, the Head Assembly (HDA), comprising the headstack, the actuater and the disk(s), were vacuum-sealed in the "black box" in clean room conditions. Following that, the PCB Assembly (PCBA) was mounted and the whole encased to form the finished product. The drive was then programmed and formatted by an Automatic PackWriter (APW), and then sent for functional testing. At each intermediate stage, the product underwent functional tests. Failures of all stages were sent to FA. The FA technical workers re-ran the various stages of analysis progressively, depending on which stage the unit failed. Where the failure resided in the HDA, it was sent to the clean room FA for diagnosis and repair.

The tasks of the SEA included:

a. Power up drive and, if unable, investigate power supply system.

b. If powered, check the error logs of each stage of the HDA functional tests. Where below acceptable limits, investigate.

c. Scope the source of error by sending commands through the different circuits of the HDA via a port on the PCBA, and observe responses using multimeters and oscilloscope

d. Open up the sealed HDA, remove the headstack and carry out necessary "surgery", e.g. re-set the read/write head position or correct its amplitude, correct for vibration, replace scratched media (disk), change or clean if actuater was unable to move due to rough bearings, or re-energise the coil/magnet.

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e. Close up and re-test.

The HDA was a high performance mechatronics device. Detailed instructions were set out in the "FA Guidelines" and in the "Manufacturing Process Instructions" (MPI). In order to use the test software (39 programmes) to "scope" for error locations, the SEA required a thorough grasp of the HDA circuit construction. The actual repair was by manual intervention, requiring mechatronic knowledge and manual skill. Where the source of failure lay in the PCBA, the unit was sent to another section outside the clean room.

The work of the Diagnostic/Repair Technician at Company E was typical of diagnosis and repair/re-work of a "failed" PCBA. With ten years of working experience, she possessed the NTC 3 in Radio Servicing, obtained part-time. Her tasks included one or more of the following:

a. Re-run the functional tests and locate the fault circuits.

b. Confirm visually that the cause was not due to open tracks, deposits of flux, improper soldering, loose components, missing jumpers, etc.

c. Carry out component tests, using oscilloscope and multimetres.

d. "Swap" components, test, re-solder or re-mount, test and clear.

e. If the PCB itself was faulty, or the item was totally non functional, return to supplying contractor.

Diagnosis required knowledge of the specific circuitry of each PCBA. In a short-run, small batch and varied product range situation, as in her case, it called for ability to read many circuit schematics and manuals, and have knowledge of many component characteristics. Besides use of the conventional workshop tools, soldering irons and measurement instruments of an electronics workshop, she also operated manual SMT chip extraction and mounting machine.

Lastly, the initial functional testing of the hard disk drive at Company A's repair centre had been reduced to simple procedures following fixed formatted steps, with automatic test and error logging. This function could therefore be carried out by an operator. The re-working of PCBAs, following diagnosis by a technical worker, was also assigned to a select number of experienced re-work operators in Company D.

E. Finishing & packing (back-end)

This was a significant stage of manufacturing, but with line functions undertaken by non-technical workers, e.g. operators. There were no technical workers directly deployed. In Company B, the test IC devices in fact went through marking, post-mark testing, visual-mechanical inspection (VMI) and Hermatic testing, before packing. Some of the equipment used incorporated state-of-the-art vision technology. A significant number of the technical workers from Maintenance supported back-end operations in the various companies, including setting up and trouble shooting (see below).

F. Maintenance of production equipment & systems

Maintenance of Production Equipment and Systems included set up, trouble shooting, yield management, preventive maintenance, and major repairs. It covered the line manufacturing, testing and back-end stages of production. In some of the companies, it included installing and qualifying new equipment, and liaison with vendors to support equipment.

This was the area from which the largest number of technical workers were reviewed, 16 in all. The division of work tended to be by the stages of production, with coverage of all technical functions in each stage by the same group. Of the number interviewed, 12 supported line manufacturing, three testing and one back-end.

The concentration of high technology, and therefore maintenance requirements, lay in line manufacturing. Of the 12, five supported fully automated production lines, while two were responsible for automatic SMT chip mounting systems. In Company B, work was not only organised in stages, but for Line support alone separate groups were responsible for set up, on line support (trouble-shooting), "major down" (stoppages and faults), "super down" (breakdowns), and preventive maintenance of the extremely sophisticated and high volume test systems; additionally, within each group technical workers specialised in individual series of equipment.

Generally, technical workers were found in three typical work situations:

a. "Islands of technology" at which many stages or sequences were integrated into the operations of a single machine or workstation; or where a single machine performed a highly sophisticated process requiring complex technical supervision.

b. "Joined lines", in which "islands of technology" and other intermediate workstations were joined in a continuous automated process, requiring total system correlation.

c. "Support" functions, generally non-sequential, which might or might not involve high technology equipment.

A good example of an "islands of technology" situation was the work of the two SMT technicians in Company D. The Maintenance Department provided total technical support of the equipment operations on the production line. The SMT Section, to which they belonged, only looked after the SMT chip mounters. Batches were typically short, so that set ups were frequent in a shift.

Both the SMT technicians were recent ITC graduates, in mechatronics engineering and industrial electronics, respectively. Their work functions for a repeat set up, included all or some of the following:

a. install/recall programme from machine memory;
b. change associated equipment as necessary;
c. off-set the board to the co-ordinates of pick and place;
d. fine tune the board orientation, rotation and alignment for perfect placement;
e. check and adjust for proper functioning, alignment, and loading action of feeders, input and output conveyers, monitors, sensors, etc.;
f. visual check for cleanliness and completeness of line;
g. test run, fine tune, until error free.

Because the production line is not continuous or joined, machine to machine correlation was not required.

For a new board, they carried out the following additional operations, based on the prototype and specifications:

a. programme or "teach" the machine
b. match the chip(s) to feeders and the board to input and output equipment;
c. test and fine tune to error free.

For regular maintenance (as well as trouble shooting), they carried out the following:

a. lubricate and change worn moving parts;
b. clean air nozzles and air filters;
c. check seals for vacuum conditions;
d. re-set (i.e. "re-teach") the machine if alignment was adrift;
e. check electrical and hydraulic systems;
f. check and re-align input and out devices;
g. replace cards where necessary (they did not "service" cards).

The technician also monitored performance, covering all associated processes and input-output functions, in effect exercising "technical supervision" over each "production island".

A good example of a "joined line" work situation was represented by the job of the supervisor, Auto Insertion (AI) Plant of Company C, which assembled PCBs for its own audio

equipment. The department had two PCB product series, for audio and stereo; and three production lines, each with axial and radial AI machines fully joined. There was only one SMT chip mounter, not hooked onto the auto lines. Over the years, old machines had been phased out and new higher performance models acquired. In this company, AI maintenance was responsible for installing and hooking up its own new machines, as well as for all aspects of maintenance.

The supervisor had 11 years of working experience, commencing straight after school, and had since obtained the NTC2 in electromechanical servicing through part-time CET. His in-company training included three overseas attachments at the "home" facility learning about new equipment and processes to be installed locally. The following functions, which the supervisor was responsible for, typified the cross-over between production and maintenance:

a. Upon release of a new product for manufacture, determine from the technical instructions what could be inserted by AI, what by stand alone machines and what by hand.

b. Confirm the PCB, parts and component characteristics, match to line and initiate modifications etc., to the latter to handle the new product item.

c. Decide sequence of insertion (could be up to 50).

d. Decide the route of insertion, (shortest route and least time).

e. Sequence the machines.

f. Programme the machines and test each to ensure programme and product can run, with no crash, no damage to product, and within time etc., specifications.

g. Hook up and test total line.

The AI production runs were relatively long. The duties carried out by maintenance technicians in shift under him included:

a. respond to line calls, trouble shoot and clear;
b. preventive maintenance (scheduled one year in advance);
c. monitor machine performance, i.e. insert rate, output rate, yield rate and evaluate;
d. prepare for overhaul, and overhaul.

All overhaul and major repairs were done on the line, by maintenance. In fact four rotating groups worked three shifts to maintain "round the clock round the year" output. In the FMS line at the Mechanisms Department and the fully robotised Parts Manufacture department, Maintenance had become responsible for production: there were no operators. The supervisor, Maintenance AI was in fact similarly accountable for production and yield.

Finally, the case of the Senior Engineering Assistant (SEA), Back End in Company B illustrated the evolving scenario in the "support" segment of the productive process, where a "mixed" environment still largely obtained. The oldest of the interviewees, with 14 years of technical work which he commenced straight after school, possessed the NTC3 in electrical installation and fitting obtained part-time about five years into his career. Although SEAs in this report are classified as supervisors, he was performing actual maintenance duties, acting as the "senior" in Back End because of his experience.

The Back End activities were extensive. They covered mark (identification imprinting) of the tested micro-devices, post-mark testing for permanency, Hermatic testing for leakage of the encapsulations, visual-mechanical inspection (VMI), including external re-work and cleaning, and packing. Needless to say, Back End operations were critical to total quality.

The activities, including their workstations, were essentially stand alone, manned by operators. The equipment, of a bewildering range, was overseen by technical workers on

shift. There were markers including stamp makers, burn-in systems, gross & fine leak testing systems including pressure vessels, "bombardment" units and steam "agers", inspecting machines, VMI equipment including lead straighteners, de-greasers, chemical wash and solder dips, and packers. In each category, there were different generations of equipment. The markers, for instance, included the state-of-the-art Lightwriter UV Laser marker, installed three months previously. The inspecting machines included the latest SMD 9000, which incorporated vision technology.

The job functions of the SEA were:

a. clear "down" equipment;
b. diagnose and repair "super-down" equipment, in liaison with vendors where necessary;
c. carry out preventive maintenance;
d. specify and instruct fabrication of, or make parts, jigs and fixtures at maintenance workshop;
e. liaise with vendors, suppliers and stores;
f. carry out special projects - currently implementing Statistical Process Control (SPC).

The diagnosis and repair of "super-down" equipment involved the following processes (also applicable as appropriate in trouble shooting "down" equipment):

a. visual mechanical inspection for misalignment, displacements, obstructions, etc.;

b. check power system, i.e. leads, connectors;

c. strip mechanical parts, oil, clean, place, adjust moving components, bushes, etc.;

d. power up and run diagnostics to check out electronic circuits (card by card, function by function) to isolate cause(s);

e. replace cards, re-set, re-test (had on occasion, but rarely in this job, to replace components on the card);

f. liaise with vendor, where field service was required or equipment was under guarantee;

g. run test batches, re-qualify and release to Back End.

The SEA's responsibilities extended to the equipment in all Back End sections. He handled the latest technology equipment, as well as the various essentially mechanical-electrical equipment. In respect of the latter, there was a need for the full range of engineering trade skills to maintain the essentially conventional equipment, including, ovens, pressure vessels, chemical fluids, boilers, as well as fabricate and "fit" spare parts in the mechanical workshops.

G. Process

Process was concerned with maintenance of yield. There were four interviewees who came under this classification. In the integration of jobs noted earlier, this function was progressively merging into maintenance duties. However, in Company B, because of the large number of batches (1,000 set ups a week), Process was a separate function. An interesting development was the recent transfer of Process from Engineering to Manufacturing, reflecting an aspect of integration. Three of the workers interviewed were from this company. The fourth was from Company A; although from the Test Engineering department, his work appeared to be largely Process.

The work of the EA in Company B responsible for the PLCC (Plastic Leadless Chip Carrier) package was typical. He not only specialised in this category of product, but only for VM inspection and Hermatic test processes. His tasks were:

a. for prequalification of new batches:

    1. to design, make (contract out if necessary) and install the handler input-output jigs and fixtures and other mechanisms

2. to determine the handler settings for the product specifications

3. to load the test software and run tests on reference batches until the desired specifications and yield were attained

4. to draw up instructions for the line operators and inspectors

b. for on-going or repeat batches:

1. to monitor yield readouts of production runs and trouble shoot drop in performance

2. to modify and improve the jigs, fixtures and mechanisms for greater yield

c. to identify and carry out projects to improve line installations, and monitor/ evaluate new equipment and materials on the market.

Process engineering called for complete knowledge of the product, the production line and detailed competence in the specialised process supervised. In this case solid grounding and experience in the mechanical engineering trades was necessary. The EA in fact had a Tech Dip in Production Engineering, with some three years of work experience.

H. QA

There were three aspects of QA: (1) incoming QA of components and other inputs, (2) outgoing QA of finished batches and (3) market QA dealing with market response, complaints and service. QC was separate and undertaken as a part of manufacturing. Two people were interviewed in this area, an EA dealing with incoming, and a leader (operator) dealing with outgoing QA.

The latter was a good example of a job with potential for non-technical workers to move into technical operations or functions without need for application of technical knowledge. The leader was in one of the final assembly departments of Company C. She was in charge of PQA (Product QA) at the line-end for radio-clocks. She supervised ten QA line inspectors and two data checkers. She trained them and had carried out the various functions before assuming her present role. Her own tasks were to:

a. to identify the samples for QA (done after packing);

b. to double check all "failed" samples, discuss with the line production supervisor and decide whether or not to reject and order "hold" on the batch. She consulted with and requested diagnosis and testing by the appropriate technical staff before decision;

c. to study the specifications of new products, and instruct and train her inspectors on them;

d. to act as reference and resource to her inspectors in case of doubt.

The line inspectors looked for:

a. visual defects, ie scratches, unconcealed weld lines, etc.;
b. construction;
c. operations (all functions operative);
d. markings, printing, and paint to specified standards;
e. packing, manuals, etc in order.

The data inspectors looked for:

a. frequency span, settings, and accuracy of readouts;
b. accuracy of speed of recording and playback devices;
c. input (e.g. antenna) and output (e.g. speakers) devices functioning to specifications;
d. alignment, balancing, etc., correct; and
e. power supply performance to specifications.

The data inspectors were required to operate a range of electronic and electrical measuring instruments, including synegen, voltmeter,

separator, antenna loop, DC & speaker load meters, etc.

The job function of QA leader was a responsible one, calling in its exercise for clear understanding of the functions (what and how) if not the why of it. No diagnosis was required. She was capable with her experience of decision-making in her function without having to tie down a technician. She had no technical background herself.

I. Service

The sole case in this category was the Service Technician (Customer Counter) of Company E. The counter handled calls in respect of all the products marketed by the company, which besides its own LAN cards and PC computer systems included other PC products. He had an ITC in electronics engineering. His tasks were:

a. Respond to calls for advice and assistance from distributors' field technicians who faced "hang" problems, and from direct customers. (Distributors were responsible for their own customer support, although the company was moving towards total support.).

b. Receive and perform first line diagnosis of equipment sent in; to repair or correct on the spot if possible and return.

c. Send to repair centre with diagnosis (if able), if there was a need for major technical work.

d. Liaise between client and centre.

Besides dealing with people, first line knowledge of the products was required. The ability to conduct logical problem analysis over the telephone and to supply technical and operational information to distributors' technicians was especially important.

J. Profile of technical work

While the product might be "electronic", the manufacturing operations in the electronics industry were the same as in other manufacturing. These included product development and industrial engineering, input, the production line, product testing, and back end. Integral related activities included process engineering, maintenance, and QA. All stages and processes used middle level technical manpower.

These carried out functions that involved the application, usually within well defined parameters, of technical knowledge and know-how. At one end, purely functional activities were "routinised" and transferred down to technical operators and engineering operators. At the other end, they were called on increasingly to assess technical data and exercise technical judgement at the "systems" and "design" levels, in terms of both the equipment as well as the product. Typical "outputs" included the set up and qualification of high performance workstations, clearance of integrated lines, and the construction and testing of PCBs. "Knowledge skills" were the first pre-requisite. The work was in the head, but backed by know-how including manual skills - for the machines and products had, in the net result, to work.

V. Training

A. Off-the-job training

This Chapter deals with the "off-the-job" training inputs which have gone to make up the knowledge and skill profile of the technical worker. It covers both formal and non formal training, the latter whether delivered externally or in company, but excludes on-the-job training. The latter is dealt with in the next Chapter as part of skill formation. The advantages outweigh the difficulties of drawing fine distinctions as to whether various forms of company and departmental training should be classified as off- or on-the-job.

B. Education

All the technical workers had completed secondary education. In Singapore, this is the General Certificate of Education "Ordinary" (GCE "O") level or equivalent, i.e. K10. This is the basic educational pre-requisite for admission to post-secondary and tertiary education and training. Four also obtained the General Certificate of Education "Advanced" (GCE "A"). One worker (only) re-sat the GCE "O" after commencing work, to improve his English Language grades. Apart from this case, there was no interest in education pursuits as such. No one was attending further education classes.

C. Technical education

The breakdown of the technical workers by, and according to the method of obtaining their current highest technical qualification was as follows:

Level	Pre-employment Institutional	CET*	Apprenticeship (EDB Scheme)**	Total
Tech Dip	10	4	3	17
ITC	12	2	3	17
NTC		3	1	4
No Qualif				4
Total	22	9	7	42

* CET = Continuing Education & Training, self financed and part-time
** Economic Development Board (EDB) Traineeship Scheme

In addition, the following technical workers were attending or had partly completely completed CET programmes leading to formal technical qualifications:

Level	Svsr	EA	Tech	OTW	Total
Adv Tech Dip	1	1			2
Tech Dip	1	1	1		3
ITC					0
NTC	1	1	3	1	6
Total	3	3	4	1	11

A further number expressed intention to do likewise, but were constrained for various reasons.

Besides the "engineering" programmes reflected in the two preceding paragraphs, one technical worker had completed the Diploma in Business Studies of the Association of Business Executives, another was pursuing the National Computer Board Diploma at a private training institution, and a third the Diploma in Business Management offered by the Singapore Institute of Management.

Thus, the technical workers were a "qualified" group. Of the 42 surveyed, 38 had a technical qualification. Of the 4 who did not, one was on the Trainee Technician Scheme, two were Operators upgraded to perform "Technical Operator" functions; only one was a Maintenance Technician, upgraded three and a half years after first appointment as an Operator, following company training in Japan. It is interesting that of the 38, nine acquired their qualification through CET, reflecting their own recognition of the requirement for further technical education and their willingness to invest time and money to cope or upgrade.

D. Apprenticeship

There is no apprenticeship legislation in Singapore, although apprenticeship provisions existed since 1955 and were comprehensively re-formulated and re-introduced in 1975. It is promoted through the support given by the training agencies and the financial re-imbursements by the Skill Development Fund (SDF). It appeals to those who need to earn as they learn, though at the cost of a bond in some instances. In 1991, the Vocational & Industrial Training Board (VITB) introduced new and improved provisions modelled towards achieving a "dual system" as practised in Germany, to create job entry skills training for the majority of school leavers not proceeding to post-secondary or tertiary institutions.

As at the time of the survey, none of the companies had yet become involved in the dual system. The survey however recorded the following instances of training received through apprenticeship or traineeship arrangements:

a. **Company Apprenticeship** - there was one technical worker whose initial training, commencing 1979, was as an Apprentice Motor Mechanic with the Singapore Bus Services. He had since completed the NTC3 & NTC2 in Electro-Mechanical Servicing and was currently a Supervisor.

b. **Singapore Armed Forces Apprenticeship Schemes** - there were two cases, going back to 1979 and 1976 respectively. One was an Apprentice Aircraft Mechanic with the Republic Singapura Air Force (RSAF) and the other an Apprentice Navy Technician with Republic Singapura Navy (RSN). After completing their contract services of seven and 10 years respectively, both joined industry. The first had since obtained his Tech Dip in Electronics Engineering and the second the ITC and then the Full Technological Certificate of the City & Guilds

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in Mechanical Engineering. Both were Supervisors.

c. **Company Trainee Technician Scheme** - one company introduced a Trainee Technician Scheme in 1990 with a batch of its own operators and new recruits with no technical background. Trainees were required in the first two years successfully to complete the NTC3 in Electronic Servicing, originally at the Electronics Industries Training Centre (ELITC) and subsequently at VITB vocational institutes, part time on company sponsorship, for confirmation as Technician. One "Other Technical Worker" interviewed came from this group. The numbers attracted were limited and wastage was high. The company has dropped the scheme. Its present approach is to develop and enlarge the role of Technical Operators by finely configured in house training for them.

d. **EDB Traineeship Scheme** - the EDB runs a number of Training Centres and Institutes offering NTC, ITC and Diploma level programmes. All trainees are enrolled in the scheme. They are paid a stipend and bonded to serve as directed on successful completion. To acquire them, companies must reimburse EDB a proportion of their training cost. There were eight technical workers trained under this Scheme, three with the Diploma in Electronics Engineering, four with the ITC in Industrial Electronics and Mechatronics, and one with the NTC2/EDB Craftsman's Certificate in Precision Machining (Tool & Die). For the NTC2/EDB Craft Certificate courses, the first two years of employment constitute supervised work experience for the latter certificate. All programmes are in specialised areas of high technology application. This form of "institutional apprenticeship" has been highly successful in meeting specialised requirements of the new high tech components of the industry.

Apart from the cases of apprenticeship recorded in (b) above, which involved "regulars" on long contract periods, there was no correlation between vocational experience in national (military) service and either their prior qualification or post-national service employment.

E. Relevance of technical education

In the make up of the technical worker, formal Technical Education provided the essential inlay of technical knowledge and basic skills which enabled learning of the production technology and skills. To the question: could they have been employed and trained to their present competence without formal training, the majority of respondents replied no. The others said it was unrealistic or it would take too long. In the case of the sole exception mentioned above, he admitted experiencing gaps, and recognised that others with formal training would "pass" him. With institutional training, companies could move quickly to be industry, company, production and job specific.

The responses to the questions on the relevance of institutional training to present job may be summarised as follows:

a. It depended on the course-to-job match. Assuming recruitment had been properly done, it depended also on the course structure, the nature of the job, and whether it was a new job entrant or a worker with longer service.

b. Some 26 of the 42 interviewees had two or less years' service with the company, and 12 had two or less years of employment altogether. Theirs reflected the experience of new appointees. Polytechnic graduates (Tech Dip holders) seemed to be comfortably deployed where jobs required more knowledge intensive skills. ITC and NTC graduates tended to fit better into the more "practical" functions. In terms of disciplines, electronics courses were a close match in narrow and specific work, such as disk drive failure analysis and component test systems pre-qualification. Mechatronics and Electro-Mechanical

Servicing graduates fared best on setup, trouble-shooting and maintenance of sophisticated production equipment. The one Technician on an FMS line was perfectly happy with his ITC in Mechatronics, but one other with the same qualification found less than a third of his training used in maintaining SMT machines. Despite recent infusions into the curriculum, Electrical, Mechanical and Production Engineering graduates experienced knowledge gaps in industrial engineering and maintenance where they tended to be used. Perhaps representative of recent appointees was a 1989 Tech Dip graduate in Electronics, from the French-Singapore Institute, who joined immediately after graduation, working in Test Systems Maintenance. He indicated 50:30:20 as between used technical knowledge acquired by pre-employment training, employer training and self-learning.

c. Where the interval since graduation was longer, institutional training inputs quickly became less directly relevant. The case of an Engineering Assistant in charge of Technical Support of Test Systems was illustrative. A 1987 ITC graduate in Electrical Engineering with three and a half years service and promoted from Technician to her present grade, her ratio of used technical and technological knowledge gained by initial institutional training, company training and self-learning was 20: 30:50. After a few years, as their work needs and company overlays grew, most technical workers felt the need to re-set their formal knowledge base and upgrade to the next higher qualification. To a certain extent, this reflected inadequacies, lack of structure, lack of certification, and perhaps too much specificity in the company training. Those that could manage it had done so or were pursing the next higher qualification through CET. This was both a bonus to the company and an insurance for optional employment.

d. Respondents at the Tech Dip level commented that institutional courses generally did not specialise for industries or processes. Electronics, for instance, usually covered Communications Engineering as well. As one of them put it, "the institution had to make a guess where I would work." Thus, besides their necessarily limited depth and practical exposure, up to half of the subject specialisations were not used in such cases. However, as another put it, "All technical knowledge is useful, and adds to understanding. You never know when it will be needed." The value of institutional training lay in the foundation for the worker to take off. The broader the technical base, the more flexible the worker. Generally, respondents at this level appreciated the two sides of the issue. They recognised that even if wider options were given, they would face the difficulty of making choices after leaving school.

e. Many respondents at the ITC and NTC level, where deployed into their areas of training, appeared to be functionally comfortable. The ITC graduates of the Japan-Singapore Technical Institute (JSTI) in particular were able to take up high-technology work. Generally, however, technical workers at this level (more so for NTC) experienced strain in coping with a limited technical knowledge base, as the evolving technology increasingly demanded this - and use of knowledge rather than physical skills. VITB graduates appeared mainly to serve a support role, although the study showed that many had successfully developed upon their training and occupied front-end positions. Others serviced the more conventional equipment and "back-end" or support jobs, with limited prospects. Some were being replaced by specifically trained or experienced Technical Operators through job re-configuration to provide these types of functions.

While there was an absence of formal apprenticeship, the companies recognised the value of EDB's pool of "ready-made" practice-oriented high tech graduates, and took advantage of it. The absence of formal apprenticeship could be due to a number of factors: availability of technically educated institutional graduates, the

knowledge intensive nature of electronics work, the rapid change of technology, the newness of some of the firms and their pre-occupation with growth, the lack of master trainers and formalised training systems, the high turnover of trained staff in a heated market, and the short production lead-times: probably a combination of all.

F. Non formal training (off-the-job)

The technical workers participated in a wide range of non formal off-the-job training courses, both external and in house, programmed by their companies. These varied from a few hours to three months, both full time and part time.

Company external training concentrated on building production specific technological knowledge and preparation for job skill formation. The programmes were diverse, from robot programming, SMT and computer languages to management of manufacturing, statistical process control, quality circles, COSEC (Core Skills for Effectiveness and Change) and equipment maintenance.

Company external programmes came from a range of providers: training institutions, like EDB institutes, the polytechnics, the vocational institutes, the extra-mural programme of the National University of Singapore, professional and industrial bodies like the Singapore Quality Institute, public training agencies like the National Productivity Board, industry training agencies like FESTO and the EDB-Matsushita Technical Training Centre, vendors, private technical education institutions, etc.

The in house off-the-job training provided by companies fell into the "must have" and "good to have". The former concentrated on firstly understanding the company and company culture, secondly the company production system, and thirdly the job. A fourth objective was preparation for introduction of new products, processes, equipment. These laid the foundation for on-the-job skill formation. Besides in house resources, vendors and consultants provided in house training.

As might be expected, the efforts of employers were centred on provision of technological knowledge and know-how, through both external and in house programmes. Over time, this was by far the larger quantum and the more relevant. The clearest cases were where a technical worker was identified for a function or project, and sent on a comprehensive programme, including line practice, to prepare for it. The majority of workers went through an induction programme varying from 1 day to 1 week. Some had individualised attachments and briefings, while others attended group courses, full-time or part-time on equipment, quality practices, etc. At the same time, there were workers substantially left to find their own feet, with on the line guidance. These tended to be in routine jobs.

Both the employer and the worker were equally involved in non formal training. But, the workers perhaps exerted the greater initiative and effort. Many had or were pursuing Computing courses. A significant number had taken modules or even full second qualifications in Electronics through CET. Their major efforts were centred on obtaining higher technical qualifications, i.e. the Tech Dip or the Advanced Tech Dip as the case was.

To the question what further training would enhance their job performance, a small number replied that the employer was providing all the training needed. The others indicated a range of "gaps" and needs. Much of these related to more structured off-the-job training on production technology, equipment and software. Much of these were also in areas of technical knowledge, some of which they were attempting to fill by self study and CET. There seemed to be a pervading sense of not being able to "see the whole picture" and in some cases not knowing what they should know. While employers concentrated on delivering what was required to achieve operational proficiency, the workers were grappling with "understanding" what they were doing. There

were other practical needs, which will be dealt with under skill formation.

Interestingly, neither company nor worker showed interest in additional non formal education. They relied on developing work skills for personal development. It is noteworthy that the responses to the question in what further ways could the company provide training brought forth requests, inter alia, for supervisory training, communications, writing proposals, leadership, and presentation skills.

The reported participation in external programmes was 54 or 1.3 per worker over his or her career, but this was an underestimate, as they could not remember, nor always distinguish between training and exposure.

It was not possible to capture in house off-the-job participation with any meaning. A lot of departmental training was indistinguishable from on-the-job training. It was a cyclic activity, repeating itself with new products, processes, and equipment.

In the cases of nine technical workers, their "in house" training included being sent to the US or Japan, in one case up to three times, to be inducted into the manufacturing of a new product, introduction of new production equipment or and to acquire the transnational's corporate culture.

G. Training profile

Overall, the typical technical worker obtained the Tech Dip or the ITC by full-time institutional training, after school and before national service. There was a one in four probability that he was pursuing an additional formal qualification through CET. There was a 1.3 to one probability that he had been sent by his company to attend an external training programme, and one in five probability that he had been sent on overseas training.

VI. Job competence

A. On-the-job training and job competence

On the shop floor, job competence meant executing the tasks of a job right, in the time and to the standards set. Executing a job required job skills, applied in the required combination to produce the work output.

Skill formation took place by the technical worker doing the tasks, until competence was achieved. It was practical learning.

On-the-job training meant the accompanying instructional and supportive acts to help the technical worker achieve skill formation.

Beyond competence was mastery, when the worker would be able, among other things, to supervise, transfer job knowledge correctly and assist skill formation.

B. Pre-requisites of skill formation

Skill formation required the following pre-requisites, generally provided by preparatory off-the-job formal and non formal training, external and in house:

1. Personal abilities

a. **Educational attainment** - in particular command of language (especially English for a technical worker in the Singapore environment) and mathematics. Knowledge of science and computing were assets.

b. **Cognitive skills** - in particular powers of logic, analytical ability, and relational sense.

c. **Personality development** - maturity and a highly developed sense of job responsibility (also known as work attitude).

2. Technical knowledge and skills

d. **Fundamental technical knowledge** - core knowledge underlying and enabling interface with the production and job functions (increasingly, this was cross-disciplinary).

e. **Basic technical skills** - ability to use common workshop, laboratory and production tools, instruments and equipment.

3. Technological know-how and job knowledge

f. **Industry** - the product, product market, and the productive process engaged in.

g. **Production function** - the specifics of the production process, organisation of work, and the standards of work.

The education, quality and the technical and technological preparation of an individual affects the skill formation curve, including the time taken. The common practice was to recruit Tech Dip holders as Engineering Assistants and ITC and NTC2 graduates as Technicians.

C. Job skills

The study revealed that job competence required the worker to develop, and effectively apply in combination, the following skills:

a. **Knowledge skills** - the application of technical knowledge and technological know-how to problem analysis during tasks.

b. **Job skills** - physical skills for setup, working, trouble-shooting, testing and maintenance of the equipment used and processes carried out.

c. **Work skills** - behavioural abilities like teamwork, communication, planning, organisation, evaluation, and related productivity skills as applied to tasks.

d. **Accumulated experience** - the "E" factor. Mastering the company's accumulated experience of the job, and company culture.

Actual skill formation varied with the individual. Therefore, on-the-job training was essentially individualised.

The combination of skills required for each job varied. It was possible to discern three separate levels of jobs, and within each different combinations of skill:

a. **The supervisory level.** There were nine supervisors/senior engineering assistants within the survey. They fell into two categories, those responsible for whole functions, and those doing highly specialised jobs. The first category required competence in the manufacturing processes supervised, in terms of the inputs, outputs and work organisation, i.e. technological knowledge. They required technical mastery of the job functions of those under them, and the full range of work skills. Responsibility focussed on output and quality. At different times, four of them were members of project teams, leading in the installation of, including training for, new product lines. They went overseas to bring back the new technology. The others (designated senior engineering assistants) were responsible for critical technical operations or high level systems. One had been assigned to work on the process qualification and yield management of the new generation of chips being tested. They tended to work in knowledge skills. In some cases they required indepth work skills.

b. **The technical level.** Some 30 of those interviewed belonged to this group. It was possible to distinguish a sub-group doing "higher" technical work. Higher technical work generally involved sophisticated software-driven "systems", which could be electronic operations such as device testing, machine-systems such FMS or PCB design requiring CAD tools. These functions required high level technical knowledge, multi-disciplinary in some cases. The remaining technical jobs fell into two broad categories in terms of skill requirements. The first were those activities that dealt with installation, line support and maintenance of technology less-intensive sub-systems and equipment, e.g. burn-in systems, and back end equipment. These required physical skills coupled with detailed technological knowledge. The latter required mechanical, electrical and electronics knowledge, down to their specific interfacing in the equipment used. Considerable work skills were also required to communicate firstly with one another. In a "major down" situation, it would not be uncommon for duty technicians to call in process and industrial engineering personnel with specialisations in mechanical, power, or software. They also needed to communicate with operational staff, incoming QA, etc., even parts subcontractors and vendor field services. The second category comprised those involved in skilled work on "work pieces". such as failure analysis and repair of disk drives and PCB boards. They required detailed knowledge of the technical design, functioning and construction of the product, e.g. down to circuit and chip level, besides "craftsmanship" in workshop and specialised instruments and tools. They needed less work skills.

c. **The routine level.** Three of those surveyed fell into this group, all without formal qualifications. They did, respectively, machine setup, QA, and Failure Analysis. Although not personally surveyed, there were others doing re-work of PCBs and "machine keeper" (auto-line monitoring an adjustment). They required knowledge only of "what" and "how" to respond to

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different errors conditions and logs, but not the "whys of it".

The demarcation between levels, groups and categories was elusive, and differed with company and production technology used.

D. Speed of training response and flexibility

The companies were dominated by fierce international competition. Survival depended on quick response to change (rapid change and parallel change), in modifications to existing products, to producing new products and adopting new technology. This transmitted itself to training. The lead-time for reaching competency, indeed error-free competency, was desperately short. Therefore, technical workers needed to get up to scratch fast.

The survey indicated that at each level technical workers were taking on functions previously done one level up, by mastering new higher level tools, equipment and processes. Some were at the same time transferring their functions to new workers or to the next level down. Therefore, besides competency, they needed to be flexible, able to learn continuously, and to undertake the next level of complexity of work.

These factors made all aspects of training important: pre-employment training, off-the-job training and on-the-job training. Without proper attention to the last, the company cannot produce efficiently.

E. On-the-job-training process

The practice of the industry was to place the responsibility for job training on the departmental manager. This responsibility was delegated in various degrees by the latter to the engineer in charge and supervisor. The latter two held the initial and update briefings, in department and off the line. They explained the production process, the "MPIs" (manufacturing production instructions), what each section and workstation was to do, the standards and special requirements. They carried out "clinics" from time to time. In one company, the engineer from R&D carried out briefings on newly designed products. In another, there was an engineer designated as training co-ordinator.

The actual skill formation process comprised four components:

a. transfer of job knowledge through instruction and guidance by the "instructor";
b. transfer of skill through demonstration, correction and evaluation by the "instructor";
c. learning and improving through doing by the new technical worker or "trainee"; and
d. overseeing, "certification" and acceptance of the output by the instructor, "mentor" or person in charge.

At job site, the practice varied. At the routine level, the process was more explicit, for semi-skilled or non-technical personnel had to be inducted into responsible technical work. At the supervisory level or where pre-employment and off-the-job training closely matched a job function, the technical worker did it almost entirely by self-learning, referring to supervisor or engineer as needed.

In the normal case, the role of "instructor" was undertaken by the section leader. In several cases, those interviewed in this category listed training as a job-function. They most commonly carried this out on shift and in the process of doing work together. They conveyed knowledge of procedure, analysis, past experience and even the quirks of each machine while assigning and checking on tasks, and answering questions. They referred the new worker to manuals, flow-charts and circuit diagrams, explaining them. Two section leaders said (with evident pride) that they scouted for suitable off-the-job training and recommended to management that their staff be sent on these. In some cases, the role of "instructor"

was not explicitly defined, and the section leader subsumed the tasks to get the job going, slipping into "training mode" as a functional necessity and part of team building. The role of "mentor" was again not always explicit, and in some cases missing. It was most commonly the de facto function of the supervisor. In some instances, the latter became the "instructor". There was no established practice of providing "instructional skills" to section leaders and supervisors.

Except for one company, there was no formal system in practice of "testing", acceptance or "certification" of the skill competence of technical workers. In the exacting world of electronics manufacturing, where customer audit was the norm and companies sought to meet ISO 9002 quality standards, this practice was confined to operators, who were regularly graded. In one company, an unacceptable drop in standards resulted in an operator being penalised by being "sent back to training". In technical work, getting the job done and acceptance of work by the supervisor were the criteria. Recognition came through the personnel reporting system. The only company to practise certification of technical workers did so, inter alia, to satisfy USA Mil Std 38510 relating to IC manufacture.

For a large number of interviewees, a major part of their learning was from their experienced colleagues, ie "tech-to-tech" (T-to-T), on the job. Part of this derived from dependence on each other, part to team-work. The learning occurred particularly at problem-solving, during setup, "down", "major down" and "super down" - when machines had to go off line - or in the course of failure analysis. A significant number said "learning by trial and error" (by T & E), "learning by observing" and "learning by doing" were their chief modes of acquiring job skills. Self-learning through manuals and schematics were the major sources of job knowledge. The ratio of 50 per cent of used knowledge being self-learnt, quoted by the case of the ITC graduate cited in the earlier chapter, was reflective of the overall situation. A Tech Dip graduate, maintaining the test system, quoted 70 per cent by self learning.

F. Learning resources & environment

The feedback from the respondents on the provision of adequate on-the-job training resources and a proper training environment may be summarised thus:

a. **Training scheme or curriculum** - there was no indication from the respondents that, excluding off-the-job courses, they had been put through structured or conscious "schemes" of on-the-job task experiences. The approach was generally individualised, on the job and to the job, sometimes ad hoc. One senior engineering assistant in Back End, where the equipment range extended to over 40, commented that learning was literally "piecemeal" and vendor dependant. He viewed that there should be more structured learning. There was no evidence of documented curriculum or instructional materials for individual jobs. One supervisor said that previous engineering assistants doing his job had "written down" notes. But, in general, such material did not appear to be systematically collected and used across the companies.

b. **Opportunity to practice** - in the typical line environment, the major machines were extremely expensive and companies did not hold stand-by units. The priority was eliminating "down time". In any case, much technical work related to "joined" or integrated operations. Therefore, practice was by "apprenticeship" to the trained technician, observing, doing sub-routines and progressively the job. In Industrial Engineering and the repair workshops of Maintenance and re-work laboratories, there was more opportunity to "open up", "work inside" and "make mistakes". In the area of equipment maintenance, the trainee technician said the best way to induct into skill was to start in preventive maintenance, then move to repair, and then go on the line. A senior engineering assistant engineer in charge of failure analysis said that the best learning configuration in his area was: start with assembly, then move to product theory and

"dry" practical work, then on-the-job. The technical workers understood the constraints. Overall, there were no frustrations over lack of opportunity to practice.

b. **Provision of manuals, instructions, procedures, etc.** - all departments had full sets of equipment manuals, and manufacturing instructions and procedures for every product. It was not evident, however, that there was always a systematic arrangement for technical workers to access these. In some cases, the manuals were "in the engineer's office". Work procedures were however generally reduced to "checklists", especially for the routine levels and for "standardised" activities. Those that needed access to computerised production logs had ample access to them. Overall, there was some feeling that there should be more access to technical literature.

c. **Library/resource centre** - given the importance of self learning, there did not appear to be a well organised library or resource centre for private technical study. However, general work information systems appeared to be good. There were excellent noticeboards, newletters, audio-broadcast services, keeping workers current, posting work competitions and achievements, and in particular promoting work skills and company culture. There were adequate PCs and terminals for private work in the department. Not all those interviewed, less than expected in fact, had PCs at home. One senior engineering assistant said the company should have an assistance scheme for technical workers to acquire PCs for home use.

d. **Time** - the most widespread comment among respondents was lack of time for self learning, not to mention private attendance of CET. Overtime work was common and unpredictable. One technician complained of no time to "stay back for a few hours" to learn. Much of the self study was done at home. The result was inability to fill in knowledge to their satisfaction. Even in job knowledge, there were many models of product and equipment coming out in rapid succession, which the technical worker would like more time to understand. One technician commented that if the company would "employ an additional person" this would give time for the others to keep up to date. He recognised, however, the constraint of trained manpower availability the company was working under.

e. **Supportive company attitude** - in general respondents felt that the companies were very supportive of and did much to provide training. Priority was naturally placed on "front-line" needs, areas of technical criticality and across-company effectiveness. The training needs of those in the "run of the mill" jobs tended to be left to on-the-job "happening" and self learning.

G. Project work

One of the most important practices was the "project team" approach. This was used for developing new lines of production. The team would comprise personnel spanning all functions and at all skilled levels. In two of the five companies, successive teams went overseas to the base where the product and production process had been prototyped. There they learnt the equipment and their installation, the specifications, and practised the productive process, until successfully producing the output. On return, they undertook the line installation, training of the staff and supervision of the run up. Besides opportunity to upgrade and effect skill transfer, the approach emphasised integration of functions and knowledge. Overseas engineer(s) usually came across to supervise the installation and run up. In both companies, the team included operator personnel. One of the companies, interestingly enough, used the same approach to export its Singapore-developed lines to other countries. One advantage of "off-production line" projects was the time built in to learn.

A number of the companies included "making improvements and innovations" as part of the job specifications of the technical worker. In one company, they were required to discuss

their "project" with their supervisor. For projects adopted, they were given the resources to carry them out, and the supervisor provided guidance. One supervisor, in another company, consciously assigned technical staff assignments to "fix" things and try experimental procedures, as his way to develop and integrate their knowledge skills.

H. Vendor field services & training

Vendors of sophisticated production machines and systems invariably provided installation, commissioning, technical backup, maintenance and training. This cut down the company's overall start up time. It meant also that the company need not carry all the expertise in house. The transfer, over time, of operational and maintenance documentation, training materials and skill competency was important. A number of technical workers said they drew a substantial quantum of their technological knowhow from questioning vendor's field staff, engineers usually. Some vendors ran training schools, where detailed exposure to the equipment was provided. The outstanding example was a technical training centre which provided three months full-time courses in their chip placement equipment.

I. "Gaps" & concerns

The majority of workers interviewed experienced "gaps" in knowledge. The common experience appeared to be striving for functional competency, filling in the gaps and preparing for change, all at the same time. Mastery appeared to be a cumulative stage, reached after several years of job and skill evolution. The technical workers reflected a wide range of "gaps" and concerns, some of which are worth reflecting on here:

a. The most pervasive comment was that "we know what is going on outside, but not inside". While this concern exists at all levels in modern technology, there were basic and specific knowledge gaps among technical workers. Some who had come up "the hard way", without modern day institutional education, lacked theory, even mathematics and science. Many technicians lacked full mechatronics background, and struggled with uncertainty in problem solving. Others were handicapped by not fully understanding how the controlling software worked. Generally there was call for more structured learning about sophisticated equipment.

b. Some commented, justifiably or otherwise, that the supervisor, section leader and colleague "may not always know" or know all. There could be mis-learning, leading later to the need for un-learning and difficulty in integrating the next stage. There was not always the time or opportunity to ask questions on the job.

c. It was not always possible to understand manuals and circuit diagrams without "going inside".

d. Learning was determined by the job. Sometimes, the learning was not in sequence.

e. There was danger of boredom once competency was reached. This could be due to utilisation at too low a level, sheer repetitiveness of the work, lack of rotation, or lack of motivation or opportunity to move to something new or undertake CET. Some felt unclear about their career development and training path.

f. There was a call to be exposed to "what other companies do" in the same area".

J. Work & learning attitudes

"Gaps", concerns and difficulties notwithstanding, the technical workers as a whole displayed remarkably positive attitudes to work and learning. This was due to the company cultures successfully built up, the sense of challenge and success enjoyed in the electronics industry, and the high dependence of the company on the judgement of the individual technical worker.

Work and learning attitudes were particularly strong among those exposed to Japanese traditions, whether at their institutions or in company. One Japanese-trained supervisor expressed his departmental work attitude: "Fix it on the line. There is no one behind you." Another technician trained at the Japan-Singapore Technical Institute said that the most valuable thing he learnt was the Japanese way of learning by aggressive inquiry. Other technical workers demonstrated the same characteristics by responding to continually changing products and technology. In a US based company, a technician took great pride in the various innovations and improvements made in her work area.

VII. Company training activities

A. People-centred orientation

Being high tech manufacturing concerns in which competitiveness rested on total factor productivity, it was not surprising that all five companies regarded the abilities of their workforce as their most critical resource. In the case of the overseas-originated transnationals, they imported strong people-centred cultures. This was accented by the Singapore environment, with its absolute shortage of manpower, and always a shortage of technical manpower relative to potential demand. These factors induced the Singapore companies to create the same operating philosophy.

Perhaps typical were the guiding principles of three of the companies:

> "....the quality of its workforce is the key to success of the Company. It is therefore the policy of the Company to ensure that every employee is trained to perform well in his (or her) job and given the opportunity to maximise his (or her) potential".
>
> "Anticipate people's development needs and fill them as fast as the changing environment demands."
>
> "Make People before Making Products".

B. Training function

All companies underlined that, as a matter of survival, they had been training nonstop since they day they began. For that matter, the same could be said of the technical worker. The primary preoccupation always was for start up of production, whether initially or of succeeding and new lines. All the companies "could not afford" to undertake the complete development of a technical worker. The policy was to recruit them from the market "ready" or as closely matched to the job as possible and train them to carry out the actual work in the shortest possible time. The enlargement of the training function developed with the need to further train and increase their competence for new and upgraded job functions or production operations, to increase productivity, job satisfaction and quality.

Without exception, the responsibility for obtaining the desired work from a worker, and therefore for the necessary training, was placed on the manager and shouldered by the supervisor. With increase of centralised planning, conduct and management of training activities, this responsibility became shared, but has remained primarily the concern of "line" management. They knew the needs and they commanded the expertise. In respect of on-the-job training, only they could do it. Those responsible for manufacturing and engineering carried the heaviest onus. In one company, the training philosophy was articulated thus: "Training is the responsibility of everyone that has staff." It appeared to be a common policy to promote from within. This further called for support of a training function.

C. Training infrastructure

One company established a Training Department with a Training Manager from the beginning in 1987, and now had two Training Managers, one for management, covering technical training, and a second for the operator staff. Two others have established a Training Department under a Training Manager in the last two years, and the fourth a Training Function (hereinafter also referred to as "department") under a Training Officer. The fifth company, the smallest, was expected to do so in the forthcoming expansion.

The training departments had between four and eight training officers directly attached to them. In addition, they called on expertise from the functional departments to conduct training.

D. Planning and programming mechanisms

While differing in stage of development, the companies with a centralised training function had installed one or more of the following policy, planning and programming mechanisms:

a. **Training policy** - all four companies had established training policies, in one form or another and disseminated down in various degrees. In one company this had been embodied in a formal Company Training Policy document, with mission statement, philosophy, training objectives, needs priorities and plans, and covering inter alia resources, benefits, responsibility, training expenses and compensation.

b. **Training needs analysis** (TNA) - all four companies called for an annual return of training needs from the operating divisions and departments. The returns asked for proposals for off-the-job training by functional area, name of worker, training needed, and justification. The latter generally required that proposals be based on the skill needs and priorities to carry out company production or development plans in the next year(s), gaps in the current skill composition of the workforce and feedback from the annual staff performance appraisal reports - of which training needs was a component.

c. **Staff survey of training needs** - one company complemented (b) above with a parallel sample survey carried out directly on staff to ascertain their perceived needs.

d. **Training plan** - the next step was integrating the preceding into a training plan, first vetting it, and indicating its implications. This was done by the Training Department. In one company, a Training Council was created, under the chairmanship of the Training Manager, with representatives appointed from all the line or "user" departments, to evaluate and prioritise the proposals, sources of training and resources. These were consolidated for presentation and approval by top management, including the recommended budgeting and provision of the training.

e. **Programming** - setting up the programmes and courses, whether external or in house, selection of third-party courses and training providers, organisation and scheduling of resources etc., were generally done by the Training Department. Nomination to attend the approved courses and their release to attend rested with line management. The approved programme was put out in an annual or more frequent training calendar.

f. **Training directory** - in two of the companies, the regular in house and evaluated external courses had been incorporated in a Training Directory of considerable impressiveness. In one company, this was grouped by levels, functional areas and programmes, extensively coded and cross-referenced. For each course, the objectives, content coverage, hours and format of training, whether leading to certification or not, and resources were indicated. These were made widely available to both management and staff and served as a reference for proposals and self-examination of needs.

g. **Inventory of training** - in two companies inventories of training completed or being undertaken by all staff had been completed and were available on-line, to consider individual needs and nominations. In one company listings of courses were made against individuals indicating who was designated for them and which were not relevant. In another, the training needs returns were going to be established in the databases, to add another dimension for individualised training needs analysis and

planning. This would permit the matching of the skills profile of jobs against the skills profile of individuals, to highlight the "gaps" to be filled by training.

h. **Developing the system** - the companies seemed to be in various degrees of developing their infrastructure. The full system included monitoring of targeted implementation. The underlying concept behind the annual cycle was working a "rolling" plan, updated and revised with implementation, experience and change.

All companies applied for Skills Development Fund (SDF) support. The company training plan was submitted for approval as a package under SDF's Company Training Scheme. However, training was generally implemented whether or not individual courses qualified for SDF approval. The company expenditure on training was not disclosed. However, one company indicated it probably exceeded the national target of four per cent of payroll, while another about two per cent. In a multi-million dollar operation, this was a lot of money.

E. Training policies & practices

The companies addressed the training needs at all levels and for all sectors, both technical and non-technical. The following generalised picture fairly reflects the evolution of training policies and practices over their growth cycle:

a. They had always recruited highly qualified managers and engineers and their initial training per se was not a concern.

b. The earliest priority focussed on the operators, as they directly acted on the product and were generally without appropriate background. They needed product knowledge and job skills to function. Their numbers were large, and they had to be brought up to date in the fastest possible time. Their training was in house, both centralised and on-the-job. This was still the largest quantum of training conducted. In one company, operator training began and still was under the QC department. In the others, it formed the major workload of the trainers attached to the Training department. Three companies tested and certified their operators according to grades, and re-tested them periodically. Among other things this was usually a client requirement to ensure quality control and a criterion for ISO 9002 certification.

c. Again, the companies always recruited only qualified persons for technical work. Technician Diploma graduates were sought after for more sophisticated work and normally appointed as engineering assistants. ITC and NTC graduates were recruited as technicians for maintenance and support work. After induction, they were expected to go straight on to the job. At both levels they needed inputs of technological knowhow and job skills to attain competence. Initially, and still substantially, this training was met on-the-job. Off-the-job training developed, according to need, with line management initiatives to lay a better foundation for on-the-job learning, and progressively became indispensable for change. Only recently had this piecemeal off-the-job training become more rationalised by centralised co-ordination and even more recently centralised planning and implementation.

The training activities recognised the whole cross section of "hard" and "soft" skill needs. In particular all companies had introduced work skills training, aiming for higher productivity. All companies, except one, had quality circles. One company had 46 per cent of its staff participating in this movement and was a national leader. Another company had trained and certified line managers as trainers for each programme of work skills. In this company, technical workers were required to attend designated training. Another offered a correspondence-cum-class programme in modules of manufacturing management leading to certification by its "parent" company abroad, which technical workers attended. Most of the

companies invested substantially in inculcating company culture.

The technical competence of the worker had now become the critical sector of training. They needed upgraded technical knowledge, all round skills and versatility to complement integration and extension of their functions, with mechanisation, automation and robotisation. Technical training was expensive, but companies were operating at levels of value added and total factor productivity that justified the cost. There was no indication whether rigorous cost-benefit analysis was done before each training proposal was approved. One company had this as a criterion in its training policy formulation.

As a general practice, off-the-job training of technical workers was carried out with in house resources where possible, for this tied the learning to the company's technology and equipment and was less costly. With expanding need to anticipate new technology not within the company, use of external providers was increasing. Training consultancies, both overseas and local, as well as vendors were increasingly used, in addition to institutions and specialised providers. Generally, companies did not lack availability of external providers in Singapore. However, institutional training tended to be generic and suitable mainly for technical knowledge and work skills. Some specialist training was too specific to certain products of the training provider. One of the issues was finding suitable technological training for the company's production needs.

On-the-job training of technical workers was pervasive and continuous, even if of varying levels in its development. Company inputs were substantial, in terms of time and effort of the line managers and supervisors. The degree of instructional methodology applied varied, from explaining on the job to supervised projects and practical assignments. At the higher levels and with the longer-service technical worker there was more reliance on self-learning. From the interviews with technical workers, a lot was also left to tech-to-tech learning. All companies now recognised that managers' and supervisors' knowledge should include instructional skills. So far, this had not yet been achieved as a standard practice.

Only one company had ventured, unsuccessfully, into a training scheme for technicians. It was not formalised as an apprenticeship and SDF was not involved, among other reasons because it also sought to recruit Malaysians.

There had been no interest among the companies in apprenticeship as a form of recruiting technical workers. One reason suggested was the newness of the companies, with their training priority narrowed to immediate production needs. Another was the lack of a centralised training function capable of developing the curriculum and managing the programmes. Yet a third reason was the lack of "master trainers". These limitations were compounded by the rapid evolution of line technology, and consequently job content and job functions.

The development of non-technical personnel, e.g. operators, to carry out "technical operator" or "engineering operator" functions appeared to be acquiring serious attention. One company was embarking on careful measurement of the skill content of "technical " jobs with a view to re-defining them for non-technical personnel to perform with training. In another company, where they were identified as "specialists", they were already carrying out highly skilled manual repair work which technicians and engineers could not do.

None of the companies were corporate members of the Electronics Industry Training Centre (ELITC), the only industry-group training facility in Singapore, which provided basic technical knowledge and skills for those without technical background leading to certification at the NTC3 or semi-skilled level. Three of the companies had sent operators there for training.

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F. Arrangements for off-the-job training

While the companies were supportive of those attending formal CET leading to qualifications, except in one case, technical workers were doing so at their own expense and in their own time.

External non formal training was generally sponsored by the company. This meant the fees were met by the company. The general practice was for the technical worker to apply to attend, from a list "approved" by the company, although designated attendance was also required where critical to the company. There were several instances of sponsored training, especially that attended on a part-time, evening or weekend basis, in which the employee "shared" in the time-cost by attending partly or wholly in his own time.

Of those attending formal CET or external non formal training on their own, a number had done so or were doing so without their supervisor's or company's knowledge or specific approval. There were equally several instances in which the supervisor or company supported self-attendances by scheduling work and leave to suit the convenience of the worker, and by giving time off for them to prepare and take their examinations. Whether sponsored or not, there was no promise of upgrading or promotion for training attendance. That seemed to be clearly a matter of job merit.

All in-house attendances were sponsored or conducted by the company. Job- or production-specific in house training was generally "compulsory", i.e. designated by the supervisor and on company time. But, there were also "good to have" in house programmes which were optional or attended on application.

G. Motivating workers to train

The survey revealed that technical workers were highly motivated to undertake training to cope with their present jobs and prepare for change. The sum total of their individual investments in time and money were substantial. Motivation and effort were not constraints in training technical manpower.

At the same time company motivation was important, if nothing more than to retain them. In the context of training, technical workers appreciated clear career development tracks to which they could aspire and the training paths to them. Companies generally had not yet moved to individualised career planning as a standard practice, but appeared to be moving there.

It was universal company policy, and accepted by the workforce, that the rewards of training were related to better performance meriting promotion and salary enhancement.

The technical workers appreciated a supportive training environment. An engineering assistant said that his company provided a very supportive learning environment, in facilities, open availability of knowledge and the attitude of his supervisors, which spurred him to maximum effort. Another said, "If and when my company thinks I need training, they will provide it. Meanwhile, my business is to get my job done."

VIII. Findings & conclusions

A. Findings

1. The evolving technological scene

The companies studied belonged to the global electronics industry. The industry demands integration of multi-disciplinary engineering processes at the highest technical and organisational level. The chain of manufacture is long, and is distributed both geographically over several countries as well among specialised producers and sub- contractors. The companies surveyed were in varying degrees part of transnational operations, three of overseas and two of Singapore origin. Three were certified to ISO 9002 and one to USA Mil Std 38510 standards.

Two of the companies were established in 1977-78, and the other three in the last seven years. Their present operations, however, represented developments beginning from the recession of 1986, with several layers of new products and product lines introduced since and up to this year. In character with the industry, the companies were dominated by the need to respond fast to the rapid evolution of demand by way of differentiation as well as new product generation. At the same time, they constantly faced the availability of more powerful and efficient production technology. Both derived from the almost frontierless advances of electronics. They were likewise dominated by the upswings and downturns of world demand. These factors created an ambient mood of frenetic change and high uncertainty - and yet of challenge - which permeated down to working levels and governed training.

The companies engaged in the relatively high-end components of their total manufacturing chain. They were involved variously in customisation of design, in process development, and in the final assembly and testing of their respective products. Size was not material, reflecting only the current component of active manufacture at the plant and the tactical use of sub- contracting.

As the companies sought to win markets, gain greater total factor productivity and beat the rising cost and non-availability of manual labour, they had invariably moved up the technological ladder in the product range, in the component actively manufactured and in production technology, with emphasis on mechanisation, automation and robotisation. As a result, the companies were technology intensive. They had become and were dependent for competitiveness on the competence and work quality of their professional and technical workers. Operator dependance was relative to scale of output, rather than process. The crucial requirement was for engineers and middle level technical manpower.

The manufacturing operations in the companies were the same as in other manufacturing. These included product development and industrial engineering, input, the production line, product testing, and back end. Integral related activities included process engineering, maintenance, and QA. The job functions were accordingly highly varied. All stages and processes used middle level technical manpower.

2. Nature of technical work

The first and most pervading finding of the study was that the technical workers worked in a "mechatronic" environment. They were invariably dealing with equipment, tools, processes and products that involved mechanical parts moving or functioning under electrical

power in response to controls by electronic devices, in some cases programmed by sophisticated software. Depending on their job function, they required in varying combinations one or more of the following abilities:

a. **Firstly**, competence in the mechanical-electrical-electronic interfacing of the workings parts of the equipment and, in some cases, the finished product. Technical workers were perforce mechatronic in orientation, whatever their in-depth specialisation.

b. **Secondly**, grasp of electronic circuitry, as well as of the computer operating system and the application software used. Technical workers had to be able to use the latter to command and programme equipment, and sometimes products - to prototype or test them. They also had to be able to use diagnostics and utilities.

c. **Thirdly**, ability to operate in a computerised manufacturing information environment, using factory information systems, statistical process control, etc. and interpret computer programmed manufacturing instructions.

Technical workers needed a spread of knowledge skills, as they were invariably called upon for multi-parameter analysis and fine-tuning for successful operation.

The second finding of the survey was that it was possible to discern three separate levels of jobs among the middle technical workers, with categories within each:

a. **Supervisory and specialist level** - first among these were those performing supervisory roles. They were responsible for entire manufacturing processes, and their responsibility focussed on output and quality. The second category was those engaged in highly specialised processes such as product development.

b. **The technical level** - this group represented the core of the technical workforce, who set up, maintained and supported the manufacturing line, product testing and back end operations. It was possible to distinguish a sub-group doing "higher" technical work, such as those responsible for pre-qualification of line and trouble-shooting of high performance workstations or test equipment.

c. **The routine level** - activities at this level comprised the necessary manual functions supporting setup and maintenance, including opening up, cleaning, repair and parts replacement. An independent component of activity was the diagnosis and "re-work" of "failed" end-products.

The distinguishing feature of a technical worker was that he used technical and technological knowledge to understand or diagnose what had to be done, and appropriate skills to do it. The distinguishing feature among the levels was the degree of technical and technological knowledge used. The quality of work was determined by the knowledge skills they possessed. Physical skills could be delegated down.

The third finding of the survey was that the configuration of technical jobs had been evolving rapidly. Induced by new products, processes and new equipment. There were four clear trends:

a. **"Specialisation"** - with scale and sophistication of line equipment, technical workers tended to be trained in depth in individual series or generations of equipment. The "general purpose" maintenance technical worker was confined to the simpler back end and peripheral equipment, or to the support workshops.

b. **"Integration"** - with the growing "islands of technology" at each workstation, technical workers were becoming responsible for the total functioning of a machine-system or machine-centre rather than pieces of equipment. There tended to be no distinction between set up, trouble shooting, yield management, maintenance and repair:

there was integrated responsibility to keep the system in production

c. **"Extension"** - with automated joining of production lines, technical workers were, increasingly, concerned not only with their workstation. They had to work back and forward "along the line" and assume responsibility for correlation, right back to the supply of inputs. They were becoming "systems technicians". More and more, responsibility for production performance transferred to the technical side as "operations" reduced and eventually became "no man".

d. **"Routinising"** - the incorporation of higher end work and responsibility was accompanied, and in fact enabled by, "routinising" of still necessary manual technical processes and procedures for diagnosis and repair, checks and controls. They were simplified, e.g. taken over by computerised tools or software, or delegated down. At the lowest level, they were transferred to non-technical people.

As a result, at each level and job, with better tools, the work of the technical worker was "up-skilling" in technical content and responsibility. They were taking on higher level functions and larger spans of responsibility, some previously done at professional level. They were called on increasingly to assess technical data and exercise technical judgement at the "systems" and "design" levels. The impact of their decisions also increased, with corresponding increase in value added. At the same time they required more technical education, and in-company product and equipment training and experience. The work was increasingly "in the head."

The fourth finding of the study was that technological efficiency was becoming interlinked, from design for manufacturability to turnaround, downtime and the rejection rate. Technical workers no longer worked in isolation or could keep knowledge to themselves. Each depended on the efficiency of the other. The usual scenario in a major problem situation was team consultation to clear it and feedback to source of the cause. This added a premium on interpersonal and communication skills, work attitudes and quality consciousness. Efficiency lay in work skills.

3. Factors determining job competence

The survey found that job skill formation required the following pre-requisites, generally provided by preparatory and off-the-job formal and non formal training, external and in house:

Personal abilities

a. **Educational attainment** - secondary education, in particular command of language (English in the Singapore environment) and mathematics.

b. **Cognitive skills** - power of logic, analysis, and a relational sense.

c. **Personality development** - maturity, a highly developed sense of job responsibility and ability to work independently (also known as work attitude).

Technical knowledge and skills

d. **Fundamental technical knowledge** - core knowledge enabling understanding of production and job functions.

e. **Basic technical skills** - common workshop, laboratory and production tools, instruments and equipment.

4. Technological know-how and job knowledge

a. **Industry** - the product, product market, and the productive process engaged in.

b. **Production function** - the production process, organisation of work, and the standards of work.

c. **Job functions** - the job.

The education, quality, technical knowledge and technological preparation of an individual affected the skill formation curve and the time taken.

The preparatory technical education and training of a technical worker created the necessary ability to learn. Where this was undertaken before employment or through Continuing Education and Training (CET), as social and or personal investment, it cut down the time and costs to the company to bring the employee up to start up and competence. With continuous upgrading of job content, this had to be on-going.

The study found that to attain job competence the technical worker had to develop, and effectively apply in combination, the following job skills:

a. **Knowledge skills** - the application of technical knowledge and technological know-how to problem analysis during tasks.

b. **Job skills** - physical skills for setup, working, trouble-shooting, testing and maintenance of the equipment used and processes carried out.

c. **Work skills** - behavioural abilities like teamwork, communication, planning, organisation, evaluation, and related productivity skills as applied to tasks.

d. **Accumulated experience** - the "E" factor. Mastering the company's accumulated experience of the job, and company culture.

Job skill formation and transfer of accumulated experience could only be provided on-the-job. This had to be backed by production, equipment and product specific knowledge - as well as supplements of more in-depth technical knowledge - provided either informally on the line or by off-the-job training. These components in the training of a technical worker had to be provided by the company, and represented its investments in its human capital. It was also a continuous and on-going commitment, with each change of job or job-content.

On-the-job training was an individualised process. Effectiveness depended, ultimately, on the extent to which a company developed and organised its capability to achieve this. It was the most crucial component. One Training Manager thought that not less than 70 per cent of the company's training efforts should be concentrated on-the-job.

5. Factors governing on-the-job training

The study found that the following factors were critical to on-the-job training:

a. **Responsibility** - while it was indispensable for companies to develop a centralised training function of considerable sophistication, responsibility for on-the-job training had to rest with the manager. Instruction and "mentorship" must be carried out by the supervisor, as part of his job function

b. **Instructional skills** - managers and supervisors had to be properly trained in on-the-job instructional skills.

c. **Methodology** - there had to be individualised training needs analysis, however formally or informally structured. This was vital for both the technical worker and management, so that they had a common understanding of the "map" of development, could sequence learning, strike a "partnership" of self-learning with company inputs, and assess progress in knowledge formation in addition to demonstrable work capability.

d. **Resources** - it was essential to provide easy access to relevant manuals, manufacturing specifications, company and industry materials and technical literature.

e. **Time** - subject to the dictates of production, technical workers needed time to learn, especially off-the-job on their own.

f. **Opportunity** - it was necessary to create structured learning situations to enhance

the process, of which projects and assignments were the most useful.

g. **Documentation** - for sound long-term development of the training function, and continuity, it was indispensable to document the skill analysis of jobs, individual training and skill profiles and training curriculum. Accumulated experience should also be captured.

6. *Company training practices*

The common practice was to recruit Tech Dip graduates as engineering assistants and ITC and NTC2 graduates as technicians, matching disciplines to job requirements as closely as possible while keeping an eye for flexibility. The former were generally targeted for the higher level technical work, though the route varied. In exceptional cases persons with less or no qualifications had been recruited, with considerable experience in lieu.

All companies were involved in training from the very first day, and had never ceased to be. In an early stage of growth, as still reflected in one case, the company took the recruited technical worker as "ready" for the job, and placed him directly on it with only necessary induction. To a large extent this was still the underlying approach in all companies. Next, off-the-job training grew to support this, and progressively enlarged to anticipate change and upgrade productivity. In 1989-90 the other companies had all established a centralised training department or function, to co-ordinate, plan, programme and implement off-the-job training. Perhaps because it was easier and made less demands on harassed line staff, "soft skill" training seemed to have taken off more. But, this is no substitute for thorough and detailed attention to "hard skills" training and attention where it most mattered: on-the-job. Attention to the latter varied among the companies, but it would be fair to say that, overall, it was underdeveloped. The component requirements listed in para 17 were present only in degrees, mainly informal and unstructured, but not fully installed and harmonised. However, corporate concern was now strongly focussed in this area.

In four companies, the training department had introduced annual returns of training needs from line management, based on which they adopted annual company training plans. One company conducted independent sample surveys of workers' training requirements, and had established inventories of the training profiles of each worker.

On-the-job training was, in all cases, the responsibility of line management. This function was mostly implicit, rather than explicit and made accountable. In some cases it tended to be "piece-meal", occurring as a matter of exigency as much as from recognition of the need, and perhaps as much again in response to requests for help from the self-learning technical workers. Although some of the companies had begun to train, and one company to certify, line personnel as "trainers" of certain of its productivity oriented programmes, line managers and supervisors were not yet systematically given instructional skills or set procedures for actual on-the-job training. Provision of training materials, reading resources, etc, varied. Overall, much remained to be developed to bring on-the-job training to a sophisticated finely matched process addressing present and future needs. There was little evidence of documentation, especially of experience. To date this irreplaceable component of knowledge was not being captured. It is one of the fruits of a systematised professional training function.

No company had considered apprenticeship. One company instituted a trainee technician scheme but had abandoned it. The reasons included lack of "master trainers", lack of training infrastructure to manage such formalised systems, their long duration and the rapid changes in electronics manufacturing. Companies seemed also disinclined because formal certified training made workers more mobile in the conditions of high turnover characteristic of the labour market. Workers for their part did not want to be bonded, and often preferred to undertake formal courses on their own.

7. Profile of the technical worker

The typical technical worker, from the 42 interviewed, was a Singapore citizen, male, single, and 24-26 years of age.

He would possess either a Tech Dip or an ITC, obtained by institutional training at either the polytechnics or the Singapore Technical Institute, an institution under the aegis of the Vocational & Industrial Training Board. He was likely to have qualified in electronics engineering. Overall, the technical worker obtained the Tech Dip or the ITC by full-time institutional training, after school and before national service.

He would be employed as an engineering assistant or technician, and be deployed either in maintenance of line, test and back-end production equipment.

For the typical technical worker the present company was likely to be his second employer. At the time of interview, he would have had 2-4 years of service with the company.

There was a one in four probability that he was pursuing an additional formal qualification through CET. There was a 1.3 to one probability (considered an underestimate) that he had been sent by his company to attend an external training programme, and one in five probability that he had been sent on overseas training.

8. Training experiences of technical workers

The technical workers fitted in well with most jobs where their technical knowledge and skills formed the core to job understanding, especially electronics graduates. Even then, often less than half their course content directly applied, as the institution programmed (not necessarily a bad thing) for employment possibilities in a spectrum of industrial jobs and industries. This was more the case in Tech Dip programmes, which were discipline-based. It was less so with ITC and was not the case with NTC training, because these were function- or occupation-based. The corollary was that Tech Dip holders were more deployable and more susceptible to promotion.

The more common experience among the technical workers was, however, significant knowledge "gaps" in handling line equipment, which were mainly mechatronic. The exceptions to the latter were ITC graduates in mechatronics and NTC2 graduates in electro-mechanical servicing. The limitation was also experienced in the repair of mechatronic end-products, e.g. disk drives. The gaps existed notwithstanding recent broadening of most institutional curricula to provide a multi-disciplinary foundation. There was an inadequate knowledge base, during fault diagnosis, to grasp the actual interfacing of mechanical, electrical and electronics and between the software, hardware and the product. Many of them attended additional courses to fill the gaps across disciplines, or had to rely on learning on-the-job. "Older" Tech Dip graduates recently transferring into the industry experienced more severe gaps in some cases than new ITC or NTC2 graduates, because their courses did not cover new knowledge or provide multi-disciplinary exposure.

The technical workers themselves stressed the need for formal technical education and training. They could not, or it would take too long to, reach competence otherwise. As a group they believed it was important for their careers to pursue additional or higher formal training. Some nine of them had obtained their present highest qualification through Continuing Education and Training (CET), and 11 were pursuing courses. There was no suggestion this should be an employer responsibility. This was personal investment, and on personal initiative. At the same time, they felt the company should support their efforts, as indeed some companies did. The workers felt a need to strike a balance in the allocation of resources and time between (over-time) work, job training and CET, probably best in consultation with their supervisors. One worker declined going on overseas company training because he was in a critical phase of his course. Another, whose

work (in an earlier job) took him to sea, had difficulty meeting minimum attendance. In this case the institution exercised special consideration. Technical workers, without saying so, regarded additional qualifications as "insurance" in case they had to find another job. It gave them mobility.

The technical workers reflected that their companies did conduct or arrange off-the-job training where needed. There was lack of a structured approach in some cases, beyond general induction. One weakness was that these courses sometimes explained "about" the equipment or process, rather than trained them. There was inadequate opportunity for "going inside" and hands-on practice. The instructors selected were not always the best people for the task.

As a group, the technical workers said that a substantial component of their on-the-job learning was through their own observation and reading (above 50 per cent) and through "Tech-to-Tech" transfer. In some cases, the company expected and relied on this as the operating mode on-the-job. While many pointed to their supervisor and engineer as their prime sources of learning inputs, the latter often did not have the time to explain and answer questions on the line. Instructional skills and degree of training supervision varied. Sometimes the supervisors also did not really know.

Technical workers as a group seemed to lack individualised training needs analysis as a preliminary to training, or in any case a structured approach to this need. Generally they also lacked guidance on "what they should know", and how they should integrate private learning, study of manuals, project experiences, etc to complement company off-the-job and on-the-job learning, and cope with problems of "depth". "Tech-to-Tech" learning held the built-in danger of mis-learning and incomplete learning, if not supervised, perpetuating it until a crisis developed. There was lack of technical literature and access to manuals and manufacturing instructions, in some cases.

Learning was a continuous activity, forced by the rate of change. Accumulated company production and product knowledge and experience quickly became the dominant component of the technical workers' knowledge framework.

B. Conclusions

1. From the viewpoint of the company

In future, if not already, the technical worker will determine the company's speed of response and the quality of production. As operators recede into supporting roles, where they do not disappear altogether, the technical workers will be the effective workforce. The survey suggests that the "hard skills" training of technical workers must today be given the most critical attention. The "run up" time to competency is money, and the quality of technical work a central determinant of productivity.

If there were to be but one conclusion emerging from this survey, it is: attend to their on-the-job training; get it done right. A new graduate however finely matched is far from ready to perform competently. A front-end company has to create the job knowledge and skills it needs. After a short while, the technical worker is cumulatively what the company has made or trained him to be. A weak training foundation will jeopardise the company in the not so long run. Well thought-through off-the-job training can significantly improve the learning curve. But, skill formation can only take place, and competency achieved, on-the-job. It deserves all the attention it needs.

If there were to be only two conclusions for immediate action, the second is: on-the-job training must be explicitly implemented as a core function of line managers and supervisors. Inextricable from this, there must be appropriate "trainer training". The involvement of the line manager and supervisor is crucial because the company's technological know-how resides with them. Ultimately, it is they who must see that skill formation is in-

dividualised, and training is identified, configured and happens.

If there were to be only three conclusions for action, the third would be: training must be installed as a full corporate function, from top down and vice-versa. The company's training plans must be recognised as part of corporate tactical planning, implementation of which represents part of new investment, to create the skills needed.

The training function is multi-layered and multi-process. There are certain activities that must be centrally done, co-ordinated or provided. Likewise skill formation must effectively take place on the line in the shortest possible time and to the standards set. Like line development or information systems, it must be implemented in full, or not at all. But, it can be built up in steps. These include creating a training department, the physical training infrastructure, and training data bases. Professional training expertise and instructional skills also have to be developed. There must be master trainers at the line. Parallel investments need to be made in curriculum, training materials and resources.

Critical skills that line managers, supervisors and line trainers must develop, as appropriate, include:

a. defining the skill configurations of key jobs, existing and new;
b. analysing the knowledge and skill profile of the individual technical worker;
c. defining the "gaps", and structure and propose appropriate training to overcome "gaps" in workers' knowledge through dialogue with the workers concerned;
d. structuring, proposing and delivering training;
e. methodically supervising knowledge building and skill formation, including self learning and "Tech-to-Tech" learning.

If companies are looking for one simple action that line managers and supervisors can take to improve things dramatically, it is for them to sit down with their technical workers to discuss and agree on a basic "development map" which will include components to be fulfilled by the worker, to offer guidance on how to attain it and to follow up and assess attainment. It will catalyse everything.

The training system must be able, at company level, to carry out these key activities:

a. co-ordinate, evaluate and prioritise proposals for off-the-job training into a training plan and have it adopted and budgeted for by the company;

b. implement external training and organise centralised in house training, in particular in company culture, productivity and work skills;

c. provide an on-line training and skills inventory of each worker for line management to use in training needs analysis;

d. provide a training directory of evaluated courses for use of line management and workers, and know what sources of new training exist;

e. provide a centralised library, and develop a common learning resource and training methodology;

f. guide, train and supervise line managers and supervisors in their training function.

It is necessary for a company, subject to its own constraints, to adopt policies that motivate technical workers to learn, find job satisfaction and create a supportive training environment. A constraint repeated by many interviewees was time to learn. As one technical worker put it, "an additional person would make all the difference." Any serious concern for training cannot avoid this issue. Even more important is creating enough time for line managers and supervisors to attend to on-the-job training. While technical workers have on their own pursued CET leading to formal qualifications, it would be good policy to make available a fair number of fellowships (or loans) for diploma, advanced diploma and professional courses,

with or without appropriate bonding, as incentive for technical workers - besides being a good investment.

Although quality circles were practised, the evidence did not suggest that this had yet formed a strong tradition among the technical workers, nor was it related to technical training. The conscious use of this "bottoms up" process to identify training needs, obtain feedback on the training problems is highly recommended.

One reason for the absence of apprenticeship would appear to be the lack of development of the training function, and perhaps a lack of understanding of apprenticeship. The other is that the critical need is for technical workers with a strong foundation of technical education rather than skill. Although limited in scope for solving high tech manpower needs, this mode allows for development of workshops and supports technical workers, providing a source of stable supply at a level where the market shortage is severe and turnover is high. A good apprenticeship programme creates a "purpose-designed" technical individual with good long-term development potential. It is also an avenue for non-technical personnel to enlarge into technical roles. With development of the on-the-job training function, this avenue is likely to be used. A not unattractive feature is the SDF support to be enjoyed. By participating in apprenticeship, a company establishes strong links with education and the public. An immediate measure would be to launch a training corps of supervisors to qualify them to be "master trainers". This would, if nothing else, contribute greatly to elevating on-the-job training practices, as the processes in training apprentices are the same as for on-the-job training.

2. From the viewpoint of institutions

The survey suggests that knowledge skills are the prime requirement of technical work, and the evolution will be increasingly in this direction. The demand is clearly for technical workers with knowledge-based, rather than skill-based technical education and training.

There is demand for the single discipline graduate, but as technological know-how becomes more complex to master, they need more foundation in their engineering discipline. At the same time, a large number of job functions today are "mechatronic" in nature. The technical worker requires almost equal basic knowledge in mechanical, electrical and electronic engineering as well as information technology, and a fifth component - some fundamental exposure to the different ways in which current technology applies these in combination in mechatronic equipment and products. Both categories of technical worker will continue to be needed. The diversity in the current programmes of the polytechnics, EDB technical institutes and VITB cater well for differentiated needs in both areas. A proper career guidance system would enhance use of the opportunities.

A more complex issue concerns the industry or sector orientation of the single discipline courses. Where a programme anticipates that a graduate will work in either communications or digital electronics, one half of the course may not be applied, although adding breadth to his technical knowledge. Even in mechatronics or industrial controls, the graduate may or may not work in automated lines. These issues are more complex than can be treated in a study of this broad nature. However, it may be possible for "options" to be offered in the final year that better prepares graduates for the industries and job specialisations of their choice in both single and mechatronic programmes, e.g. robotics, disk-drives, FMS, micro-electronic technology, etc. With specialisation, these could expand the course coverage of mechatronic applications, coming one step closer to on-the-job needs.

Based on the experience of those interviewed, a conventional two-year full-time programme does not create adequate potential for a middle level technical worker in front-end electronics manufacturing, even if the initial "job fit" may be good. He is soon out of depth, and needs

proportionately greater time and company investment in additional preparation to master the knowledge skills of new high-end jobs. The desirable norm should be three years, or the equivalent in hours, allowing more time for both specialisation and project-type work in actual industrial applications.

The technical workers and companies utilised the CET programmes, both formal and non formal, of the institutions to a great extent in complementary upgrading of technical knowledge and filling "gaps". These programmes are as important as the full-time training in their contribution to technical worker development. Quite a number of Tech Dip holders obtained NTC2 qualifications to provide their mechatronic base. There is scope here to meet specialised industrial needs through endorsement modules, not includable in the main diploma programmes.

Where companies need very specialised equipment training, they are willing to pay for it. A vital training resource is the availability of vendor training centres and programmes and, in the area of work skills and productivity development, the services of the National Productivity Board and training consultants. Vendor field services and training packages also form an invaluable source of on-the-job learning.

The institutions should examine ways to improve entry into the diploma and advanced diploma courses. In one case, an ITC graduate received his results so late (three months) that he missed applying for admission to the Tech Dip course and had to wait a whole year. An ITC graduate from JSTI who had "A" levels found that he had to do a three year part-time course to obtain the diploma. Technical workers with the NTC2 requested that NTC1 part-time be made available, not necessarily through employer sponsorship.

3. The viewpoint of the technical worker

The clearest conclusion for the technical worker is that his career depends on the ability to learn. At the personal level, therefore, the technical worker must work at sharpening learning skills, including command of language, analytic and relational skills and computing ability. Equally important would be inter-personal skills and a deep understanding of the roots of work quality and total factor productivity in the company. Above all, the technical worker must develop the techniques of aggressive inquiry, pursuing question, problem or doubt until fully cleared up.

The technical worker cannot rest on competence in his job. He must aim for mastery. He must be ready for change. He must progressively upgrade technical knowledge and widen his command of company technological know-how. The immediate objective would be the Tech Dip or Advanced Tech Dip as appropriate. Those moving into supervisory or training positions should consider formal training in these areas. The technical worker cannot wait for the company to train him further. He must invest his own time and money to do so.

Finally, the technical worker must have a "development map". He must know what he should know, or establish this, and methodically pursue it, adjusting and modifying as requirements change.

4. Beyond the present

With take over of many diagnostic processes by electronic tools and systems, backed by automatic factory information recording, simpler technical functions have been transferred to non-technical workers, i.e. technical operators or engineering operators, relieving technical workers to concentrate in knowledge skill areas. As the companies were on their expansion curves, they were short of operators as well. Automation was generally applied in new lines, to overcome the shortage of workers. Further mechanisation by and large affected

only handling functions "between jobs stations", so that there was no displacement of workers. But the transfer down of mechanical technical processes obviously points the way for upgrading and continuing careers for operators and re-trained older workers. More important, it is a means to conserve scarce technical manpower.

There appeared to be a requirement for middle level technical workers in the area of sales, consumer education, customer after-sales service, training, and technical backup. An area not covered, but critical to the industry, was the quality of vendor field services for highly sophisticated products. The middle level technical worker would have major roles in these sectors. They also provide career avenues for mature technical workers.

Lastly, in the light of this study, the problem of "de-skilling" emerges as a negative view of the evolutionary process taking place. What can be "routinised" should be automated and passed down, releasing technical workers for up-skilling. The real issue is training them for the next generation of specialised, integrated and extended job functions, provided they are trainable. This emphasises the central message from the study that the technical worker must be seen as a deployable resource created by the company. The more thoughtful, anticipatory and thorough the total training process, the more ready the technical worker is for deployment as soon as releasable.

The manpower supply and industry-based training support infrastructure has been undergoing changes to anticipate and better support technical worker training. Expansion of university and polytechnic education will lead to their enrolling up to 65 per cent of all secondary school-leavers. VITB's new apprenticeship initiatives towards a "dual system" aim to provide a route for the majority of the remainder, through job-entry skill training. The electronics industry will have to compete for its supply of new job entrants by offering training "up front", which all other sectors are being encouraged to do. Apprenticeship cannot be avoided.

The Report "P2000"[3] of the National Productivity Board (NPB), which set the national strategies for the decade, sums up the key corporate training objectives companies should be looking at:

> "Training will have to be planned, structured and undertaken to meet the business goals of companies."
>
> "In the 1990s, trainers should be regarded as performance managers, as they are responsible for training up our human resources."

The Report of the NPB's National Advisory Panel on Trainers, "A World Class Trainer Infrastructure"[4], makes comprehensive recommendations for a national level trainer development infrastructure. It will be up to companies to utilise these initiatives and to gear up their in house training and trainer capability. Technical workers of the flexibility and quality needed will not be available otherwise, and will be lost to companies who do put their money in training.

Footnotes

[1] J. Oliveira & G. Pillay. *Training for new work technologies in Singapore*, Geneva, ILO, 1992. Training Policies Branch Discussion Paper No. 96 & J. Oliveira & G. Pillay. *The technology of technology transfer,* Geneva, ILO, 1992. Training Policies Branch Discussion Paper No. 93.

[2] Stock Exchange of Singapore Dealing and Automated Quotation (SESDAQ) System.

[3] "Productivity 2000", Singapore, National Productivity Board, March 1990.

[4] National Advisory Panel on Trainers. *A world class training infrastructure*, National Productivity Board, Singapore, October 1991.

Annex I

Middle level technical qualifications (in Singapore)

Skill certification

The Vocational and Industrial Training Board (VITB) is the national authority for skill standards, certification and training development.

The National Trade Certificate (NTC) System installed in 1973 is the basis of developing skills standards and certification for trade, craft and industrial skills. There are three levels:

a. NTC 1 — The standard of the advanced or "meister" level skilled worker, attained by an NTC2 holder after some years of work experience and successfully completing a one year full-time advanced course at this level.

b. NTC2 — The standard of a competent craftsman, journeyman or skilled worker, attained on successful completion of apprenticeship or a two year full-time trade course.

c. NTC 3 — The standard of a semi-skilled worker, attained after a one year trade course (excluding pre-vocational or basic skills training) or completing an apprenticeship or traineeship at this level.

The NTC3 and NTC2 qualifications may be obtained through the public trade tests conducted by VITB. NTC1, introduced only in 1987, is still available only as a course qualification.

Besides VITB's own full-time and part-time courses, some institutes and the training centres of the Economic Development Board (EDB), industry-based training centres, and more recently, private training providers conduct courses leading to NTC certification.

VITB also awards Certificates of Competency (COC) in various single basic trade skills, available through the Public Trade Tests System.

With recent extension, under the dual system, of industry-based training and apprenticeship in the service sector, VITB has expanded the one-level approach to certification. Thus, the retail assistants' training scheme leads to the Certificate in Retail Sales, and apprentices in office practice to the Certificate in Office Skills.

Technician certification

At the technican level, VITB awards the following two certificates on successful completion of two year full-time institutional technician courses:

a. Industrial Technician Certificate (ITC) — For engineering courses

b.	Certificate in Business Studies (CBS)	For business studies courses

Besides VITB's own courses, one EDB institute (namely the Japan-Singapore Technical Institute) offers a two year full-time course leading to the ITC.

Polytechnic-level technical education and training is three years, in all cases leading to the Technician Diploma (Tech Dip).

There are three polytechnics: Singapore Polytechnic, Ngee Ann Polytechnic and Temasek Popytechnic. A fourth will commence in July 1992, the National Polytechnic. Two EDB institutes, the German-Singapore Institute and the French-Singapore Institute also offer three year courses at this level leading to the Diploma.